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THESIS

**A HIGH-VALUE-BEST-VALUE APPROACH TO PUBLIC
SHIPYARD HUMAN CAPITAL MANAGEMENT TO
IMPROVE SHIP AVAILABILITY**

by

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September 2015

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CAPITAL MANAGEMENT TO IMPROVE SHIP AVAILABILITY**

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ABSTRACT

One of the problems faced by public shipyards is delays in completing maintenance, upgrades, and overhauls on ships. The general trend is for ships to be delivered behind schedule, which impacts the U.S. Naval Fleet's operational readiness and increases the overall cost burden of availabilities to the U.S. Navy. This study investigates the current public shipyard architecture, the contracting vehicle utilized to award shipyard availability contracts, and the relationship between the public shipyard permanent workforce and the contingent workforce. The investigation consists of analysis of public shipyard availability data and examination of the current architecture of public shipyards. The result of the analysis is the development of a proposed High-Value-Best-Value (HVBV) system-of-systems approach to managing human capital and contracting efforts in public shipyards. The HVBV system-of-systems approach is intended to increase worker-human capital, including effectiveness and efficiencies, by creating an integrated product team between the permanent and contingent shipyard workforce. Additionally, the HVBV system of systems utilizes the "best value" contracting approach by selecting the highest performer for the lowest cost, ensuring high performance and minimizing shipyard risk and delays by forcing accountability between the shipyard and the contractor.

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LIST OF ACRONYMS AND ABBREVIATIONS

BLS	Bureau of Labor and Statistics
BRAC	Base Realignment and Closure
CAD	Computer Aided Design
CNO	Chief of Naval Operations
CPS	Current Population Survey
DOD	Department of Defense
DPIA	Docking Planned Incremental Availability
DSRA	Dry Docking Selected Restricted Availability
EMMI	Energy, Matter, Material Wealth, Information
EOH	Engineering Overhaul
EQW	Educational Quality of the Workforce
ERO	Engineering Refueling Overhaul
FY	Fiscal Year
FTE	Full-Time Equivalent
GAO	Government Accountability Office
HCM	Human Capital Management
HVBV	High-Value-Best-Value
IMF	Intermediate Maintenance Facility
INCOSE	International Council on Systems Engineering
IPT	Integrated Project Team
KSA	Knowledge, Skills, and Abilities
MEIN	Metastable, Internally agile, Externally Adaptive, and are Formed by NON-Reciprocal Action
NA&ME	Naval Architecture and Marine Engineering
NAVSEA	Naval Sea Systems Command
NNSY	Norfolk Naval Shipyard
OMB	Office of Management and Budget
PBSRG	Performance Based Studies Research Group
PHNSY	Pearl Harbor Naval Shipyard
PIA	Planned Incremental Availability

PIRA	Pre-inactivation Restricted Availability
POA&M	Plan of Action and Milestones
PMA	President's Management Agenda
PNSY	Portsmouth Naval Shipyard
PSNS	Puget Sound Naval Shipyard
RMC	Regional Maintenance Center
SE	Systems Engineering
SoS	System of Systems
USD AT&L	Under Secretary of Defense of Acquisition, Technology, and Logistics
U.S.	United States

EXECUTIVE SUMMARY

One of the major problems faced by U.S. public shipyards is delays in ships' completing availabilities. In general, the majority of ships are delivered behind schedule. This delay increases the number of ships simultaneously undergoing availabilities, lengthening all availabilities duration, which in turn increases the number of ships the Navy needs to perform its operational requirements and operational tempo. A larger fleet requires more sailors to operate the ships, which is yet another cost burden to the U.S. Navy. Although the problem of shipyard availability delay is extremely complex and multifaceted, the current shipyard architecture with regards to contracting and human capital management hinders the on-time availability delivery of ships.

The current shipyard architecture can be evaluated based on the contracting vehicle utilized to award contracts and the human capital management structure. Currently, the shipyards contract based on a "best price" practice. "Best price" proposes selecting the contractor that can perform the task at the lowest price without fully considering past performance and risk mitigation techniques, which are proven to minimize cost and schedule overruns. The human capital management structure is shown through the current shipyard relationship between the shipyard, permanent workers, contractors, contingent workers, and the unions. These relationships are extremely complex and detailed. The relationships can be simplified by decomposing the shipyard architecture into a combination of three interacting systems: the shipyard/permanent employee system, the shipyard/contingent worker system, and the union/contingent worker system. Through an analysis of these systems, the permanent worker and the contingent worker are shown to work in parallel on the same task which decreases their overall human capital effectiveness and yield the shipyard experiences.

This thesis proposes a new shipyard architecture called High-Value-Best-Value (HVBV), aimed at changing the contracting vehicle used to award shipyard contracts and the human capital management strategy currently implemented by the public shipyards. By implementing HVBV, the shipyards will award contracts based on contractor past performance and risk management techniques and also encourage permanent and

contingent workers to form integrated project teams, empowering the workers. Worker empowerment will increase productivity and effectiveness thus increasing the human capital yield of each employee. By increasing each worker's human capital yield, the shipyard will realize a more dedicated, proficient workforce aimed at taking ownership of their tasks which can improve the quality, and shorten the length of shipyard availabilities.

In the "Enhancing Contract Performance Outcomes" panel from *Proceedings of the Fourth Annual Acquisition Research Symposium Thursday Sessions Volume II* held on May 17, 2007 at the Naval Postgraduate School, Sullivan and Sullivan showed that Arizona State University's Dean Kashiwagi's Performance Based Studies Research Group's "best value" approach was able to be on budget with no contractor-generated cost change orders and meeting the client's expectations 98% of the time. By creating a model for shipyard availabilities based Kashiwagi's "best value" approach and data provided electronically by NAVSEA 04 in April 2015, a what-if analysis to compare the existing system to the proposed, new "best value" system was conducted. The results of the model showed the U.S. Navy would realize an average savings of \$4.98 million per availability instead of costing the U.S. Navy an additional \$4.65 million in the current shipyard availability architecture.

LIST OF REFERENCES

Sullivan, Kenneth and Marie Sullivan. 2007. "Enhancing Contract Performane Outcomes." in *Proceedings of the Fourth Annual Acquisition Research Symposium Thursday Sessions Volume II*, NPS-AM-07-004: 445–459.

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I. INTRODUCTION

The approximately 250-ship U.S. Navy requires nearly constant upkeep to maintain the current operational schedule and missions required by the United States. At any one point in time, multiple ships are undergoing maintenance, upgrades, and overhauls (commonly referred to as availabilities) in the U.S. Navy's four public shipyards. The four public shipyards are tasked with the responsibility to provide depot-level maintenance and other maintenance services to the fleet. The public shipyards must flex to the ever-changing operational demands and to the varying size and composition of the war-fighting fleet. Over the past 50 years, the U.S. fleet has cut its ship inventory in half and has changed the composition of the fleet; all of these factors affect ship availability duration (Riposo et al. 2008).

The majority of ships are delayed in completing public shipyard availabilities. Although there are multiple factors that contribute to the duration of ship availabilities, the current means of contracting and managing shipyard work hinder the on-time availability delivery of ships. Currently, the shipyards' contracts are based on a concept of "best price." "Best price" aims at awarding contracts to the lowest-priced bidder without fully taking into account past performance or risk mitigation techniques that are known to reduce cost and schedule overruns. Additionally, the current permanent and contingent shipyard worker experiences lower effectiveness due to a process-burdened architecture. Over time, the current shipyard architecture has fallen to legislative changes, contract incentives, and inefficient combining of workforce teams. This difficulty is not a management problem, but rather an approach to carrying out business driven by an ineffective architecture. The public shipyards need a new architecture able to accommodate the unanticipated risks associated with availabilities, and with the ultimate goal of reducing cost and schedule overruns.

A. PURPOSE, GOALS, AND OBJECTIVES

This study investigates the current public shipyard architecture, the contracting vehicle used to award public shipyard contracts, and the relationship between the permanent shipyard workforce and the contingent shipyard workforce. The research objective is to apply systems engineering methods to develop a new model for the public shipyards as a proposed solution to the latency and cost increase in shipyard availabilities. The proposed High-Value-Best-Value (HVBV) shipyard system of systems provides a holistic view for addressing the issue of shipyard availabilities being delivered behind schedule.

This thesis addressed the following questions:

1. What are the impacts of permanent and contingent workers in the private sector as well as in public shipyards on work effectiveness?
2. How can managing human capital improve the permanent and contingent workforce human capital yield in public shipyards?
3. How does the current architecture of a public shipyard reduce the effectiveness of permanent shipyard workforce and the contingent shipyard workforce?
4. How might the current shipyard model be improved to decrease the number of late availabilities delivered by the shipyard?

When ships are delivered behind schedule, it impacts the total number of battle-ready ships, and the U.S. Navy and United States at large suffer. By proposing a new systems engineering approach to public shipyard contracting and the interaction between the permanent shipyard workforce and the contingent shipyard workforce, the efficiency workforce should increase, and the delays in ships completing availabilities should decrease, providing an overall cost savings to the U.S. Navy.

B. SCOPE AND METHODOLOGY

This thesis analyzes the public shipyards through system engineering techniques and focuses on two key areas, contracting and human capital management, where the shipyards can improve in order to increase the number of on-time availabilities. The eight chapters in this thesis align with the themes and activities of systems engineering.

Chapter II provides a detailed overview of the permanent and contingent workforce found in industry and in the Department of Defense (DOD). Chapter III presents a comprehensive look into human capital management, its implications, and architectures and processes. Chapter IV details the current U.S. public shipyards, their roles and responsibilities, the contracting vehicles used, and the shipbuilding industry's concerns. Chapter V discusses systems engineering and provides a detailed discussion of systems and systems of systems. Chapter VI examines the current shipyard system and its unintended consequences. Chapter VII proposes a new HVBV approach to structuring and managing a shipyard intended to improve worker efficiency and on-time ship availability delivery. The eighth, and final, chapter discusses the results of the thesis relative to the proposed research questions and addresses the need for further research concerning this topic.

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II. PERMANENT AND CONTINGENT WORKFORCE

The supply of labor is necessary to meet the changing demands for completing tasks. Organizations must manage the labor supply to respond to changes in demands. Therefore, full-time, part-time, and temporary positions may arise as a natural consequence of managing human capital to satisfy the fluctuating organizational needs. For the purpose of this thesis, the workforce as a whole is divided into two main categories: permanent workers and contingent workers. The difference lies within the architecture of the employment relationship between the organization and the individual; the type of and access to organizational benefits that are structured according to competitive factors, incentives, and laws; and the overall desires and goals of the organization. This chapter provides a further explanation of the similarities, differences, benefits, and drawbacks of both permanent employees and contingent employees as they relate to the DOD.

A. WHO IS THE PERMANENT WORKFORCE?

Dual labor market theory divides the entirety of the labor force into two distinct categories: standard or traditional workers, referred to as permanent employees in this thesis, and non-standard workers, referred to as contingent workers (Mastracci and Thompson 2009). Permanent employees are defined as regularly scheduled employees receiving human resource benefits from their benefactor company; permanent employees have an explicit contract for ongoing employment (Arthur 2001).

Although the initial hire into a permanent position at a shipyard may be difficult to obtain, once hired, the employee is nearly invulnerable to the economic market fluxes when compared to private sector employment. This sense of job security keeps the demand for federal employment and employment in shipyards high. The high demand causes employees to take internships or initially lower-paying jobs to gain access to permanent federal government employment in shipyards (Mastracci and Thompson 2009).

For all practical purposes, permanent employees enter into “at will” contracts, which are the norm across the United States. “At will” employment allows the employers “to discharge or retain employees at will for good cause or for no cause, or even for bad cause without thereby being guilty of an unlawful act per se. It is a right which an employee may exercise in the same way,” at any time (Nosal 2001, 187). Either the employer or employee may singly terminate the employment contract without justification. There are three major exceptions to the “at will” employment doctrine: public-policy exception, implied-contract exception, and covenant of good faith and fair dealings (Muhl 2001). Only six states have recognized all three exceptions: Alaska, California, Idaho, Nevada, Utah, and Wyoming (Muhl 2001). For their employees, there is no difference between permanent and “at will” employees. Four states, Florida, Georgia, Louisiana, and Rhode Island, do not recognize any of the three major exceptions. All other states recognize some combination of the exceptions (Muhl 2001).

The public-policy exception of the “at will” employment doctrine specifies that an employee is wrongfully discharged from employment when the termination is contrary to explicit, well-established state public policy (Muhl 2001). Muhl further states that firing an employee who refuses to break the law for a company or who files a worker’s compensation claim is an example of the public-policy exception. 42 of the 50 states recognize some form of a public-policy exception to the “at will” employment doctrine (Muhl 2001).

The implied-contract exception is the second major exception applied to “at will” employment doctrine and is recognized in some form by 38 of the 50 states (Muhl 2001). When the employer and employee form an implied contract despite the fact that no written contract may be present, the implied-contract exception occurs. The employee may expect job security from the employer due to verbal or written representation provided by the employer. The verbal or written representation can occur through an employee handbook or a hiring official’s verbal representation to the employee (Muhl 2001).

The covenant-of-good-faith exception is the least accepted of the “at will” employment exceptions, with recognition in only 11 states, as it is the furthest deviation from traditional employment “at will” doctrine (Muhl 2001). Interpreted to mean that a covenant of good faith and fair dealings exists with every employment relationship, employers are prohibited from terminations made in bad faith or motivated by malice. Additionally, all employment personnel decisions are subject to a “just cause” standard (Muhl 2001).

The difference between permanent or “at will” workers (simply referred to as permanent workers) and contingent workers is that, for contingent workers, the terms of employment are generally expressed upfront at the time of hire. In the shipyard industry, the terms of employment are expressed in the initial and any follow-on contracts issued by the government. Those contingencies are different from the stipulations put forth for permanent workers. For example, a contingent worker would face the same at-risk position during an economic downturn as an “at will” employee. However, as a general practice, the permanent worker has an advantage over the contingent worker in remaining longer with the company in an economic downturn because the company will dismiss the contingent workers before dismissing the permanent workers (Langford 2015, personal communication).

Due to the variation in state labor laws, there is no national standard for employment agreements for permanent workers. A blend of state labor legislation as well as overarching federal law mandates the content of each company’s permanent employee work agreement. However, common clauses and themes emerge through all permanent employee work agreements. First, a statement including the parties involved in the agreement—including their contact information, the position, title, duties, and responsibility of the new employee—along with the commencement date and term, and any probationary period required is customary (Langford 2015, personal communication). Additionally, conditions for continuation and dismissal, the lawful directions that cover the employment, the obligation for parties to act in good faith in performance of contract and duties as employees and employer, the company’s policies and rules and finally severability and termination of employment is added. The hours of

work, location of work, conditions of work, and any associated job specifics such as equipment, transportation, travel, reimbursement or any restraints may be discussed. Next, the employee compensation and benefits are discussed to include: salary, the superannuation guarantee contributions for retirement and healthcare, and vacation entitlements. A non-solicitation clause and a confidentiality clause are also standard (Langford 2015, personal communication).

The permanent workforce in the U.S. Navy public shipyards—Norfolk Naval Shipyard (NNSY), Pearl Harbor Naval Shipyard (PHNSY), Portsmouth Naval Shipyard (PNSY), and Puget Sound Naval Shipyard (PSNSY)—are government, civilian, or military personnel. In fiscal year (FY) 2007, the average workforce composition of the permanent workforce for each of the four public shipyards was as follows: NNSY: 90%, PSNSY: 86%, PNSY: 77% and PHNSY: 86% (Riposo et al. 2008). Federal law, colloquially called the 50/50 rule, stipulates the shipyards are required to spend more than 50% of the funding received to execute depot maintenance in house by their permanent workforce. The 50/50 rule limits the amount of money the private sector can receive. The spending limitation limits the number of contracts let and thus limits the percentage of contracting personnel (Riposo et al. 2008).

B. WHO IS THE CONTINGENT WORKFORCE?

The term “contingent workforce” is typically used as an all-encompassing phrase to describe all work agreements that vary from the permanent employee work agreements described previously. Arthur’s *Employee Recruitment and Retention Handbook* (2001, 190) defines a contingent worker as, “those individuals who perceive themselves as having neither an explicit nor implicit contract for ongoing employment.” Conversely, the Bureau of Labor Statistics in their article *Contingent and Alternative Employment Arrangements* (2005, 1) defines contingent workers as “persons who do not expect their job to last or who reported that their jobs are temporary.” The U.S. shipyards classify their contingent workforce into five separate categories: seasonal workers, borrowed workers, apprentices, contract, and temporary employees (Riposo et al. 2008).

All definitions of the contingent workforce have a common theme. A contingent workforce has neither an explicit nor implicit contract for ongoing employment. They have specific start and end dates. Explicit contracts specifically detail the terms and requirements of the contract in writing, are formally agreed upon, and signed by both parties involved (David 2005). Conversely, implicit contracts are an understanding between the employer and employee that they continue “at will.” The contingent workers are subject to the immediate needs of the employer. Contingent workers have no expectation of being employed over an extended period and are told so, explicitly. The short job tenure of contingent workers compared to permanent workers leads to the contingent workers having very little job security (David 2005). This lack of job security, healthcare, and other job related benefits often creates insecurity and stress not only on the worker but also the worker’s family, which can negatively affect the employee’s productivity (Liu and Kolenda 2012).

Contingent workers are less likely to work in jobs that require extensive training because they are presumed to already have the prerequisite knowledge, skills, and abilities (KSAs) to complete the task at hand (Paul and Townsend 1998). Although contingent workers may cost more than their permanent-worker counterparts because the company does not have to pay the contingent worker benefits, associated training, or retirement, these contingent workers do not see the benefit of these higher salaries because a portion of the contingent worker’s wages go to their parent agency (Paul and Townsend 1998).

C. TYPES OF CONTINGENT WORKERS

The Contingent Work Supplement in the Current Population Survey (CPS) by the U.S. Department of Labor Bureau of Labor Statistics (BLS) defines contingent workers as “persons who do not expect their jobs to last or who reported that their jobs are temporary” (Bureau of Labor Statistics 2005, 1) and “workers who have no implicit or explicit contract for ongoing employment” (Cohany 1996, 1). According to the BLS February 1995 CPS, 12 million persons or 10 percent of the working U.S. population were classified by one of the four categories of contingent workers (Cohany 1996).

The BLS further segregates the contingent workforce into four different subcategories: independent contractors, on-call workers, temporary help agency workers, and workers provided by contract firms. Independent contractors are usually identified as self-employed contractors, consultants, or freelance workers. On-call workers are employed on an as-needed basis. On-call workers may be employed over the span of multiple days or weeks at a time, or for a shorter duration of a day or two. Temporary help agency workers are employed by a temporary help agency to perform work for a given company. Finally, workers provided by contract firms are employees hired by a company and contracted to work for another company, and are typically employed for longer periods of time and work at the customer's jobsite (Bureau of Labor Statistics 2005). A more thorough analysis of non-DOD contingent workers can be found in Appendix A.

Conversely, the four U.S. Navy public shipyards break the labor force into seven distinct categories (Riposo et al. 2008, 39):

1. Permanent, full-time employees who work year-round
2. Military, uniformed members who provide maintenance services [for the purposes of this thesis, permanent employees and military members are classified as one group, discussed in section II.A]
3. Seasonal, full-time employees who are guaranteed at least six months of work per year but might not work year-round. Seasonal employees maintain benefits when working. There are also so-called term seasonal employees, who are hired for more than one year but less than four. They can be released and rehired as needed. They maintain benefits while in active status
4. Borrowed workers, who are usually permanent employees on loan from another public shipyard or from one of the two private nuclear shipyards
5. Apprentices, who are typically new employees who are enrolled in a training or apprentice program associated with a production trade. The apprentice's category includes all civilian permanent and seasonal employees who are enrolled in a training or apprentice program. Apprentices are in the production trades and can be permanent or seasonal hires. Trainees [apprentices] are individuals who receive training for an engineering job, support position, or other nonproduction shop

6. Contractors, who are brought into the shipyard in any capacity beyond the ones previously described, and whose labor is secured through a contract
7. Temporary employees, who are similar to contractors but who can be released by the shipyards at any time

The shipyard categories of labor can be mapped to the BLS categories of contingent work. The obvious correlation is permanent and military employees to the in-house labor for the shipyard. Contractors can be mapped to workers provided by contract firms. Temporary employees are mapped to temporary help agency workers. Seasonal workers, apprentices who are not permanent workers, and borrowed workers from the shipyards can correspond to on-call workers.

D. COMPARISON BETWEEN STANDARD WORK AGREEMENTS AND CONTINGENT WORK AGREEMENTS

Although permanent workers and contingent workers can perform similar tasks for a company, their benefits and work agreements vary drastically. Permanent workers have a variety of different titles they are referred to as: traditional workers, core workers, regular workers, or standard workers. In this thesis, these types of workers are referred to as permanent workers, or employees holding a standard work agreement. Permanent workers are generally thought to boost the productivity and overall profitability of the company by promoting a feeling of company loyalty, increasing the overall workforce's skill level, and allowing for a sense of flexibility and security of the employees in standard work agreement (Stirpe, Bonache, and Revilla 2014).

There are some dramatic differences when comparing permanent workers to contingent workers. First, with regards to firing for cause and layoff policies, employers are required to follow their company policies. The company policy may be to place permanent workers on a set probationary period, show an extensive paper documentation trail recording counseling and training before a permanent worker can be terminated or maybe other actions dictated in the company rules and regulations. If the company rules and regulations are not followed, the firing may be reversed with penalties assessed to the employer (Langford 2015, personal communication). Additionally, when choosing which employees to fire, permanent workers are generally the last to be released from their job.

The firing hierarchy begins with contingent workers because the permanent worker is entitled to costly severance benefits and the company could be at risk for litigated action if not handled properly (Bidwell 2009).

Contingent workers, however, are usually the first employees to be laid off if the company encounters a problem employee or hits an economic downturn (Bidwell 2009). The company does not have any restrictions on terminating the contingent worker's employment contract. Moreover, their contract explicitly allows for termination of a contract at any time for any reason (Bidwell 2009).

The company's view of personal career development and performance management also drastically differs between permanent workers and contingent workers. Bidwell states the company becomes personally invested in the permanent worker because these workers are the guaranteed future employees for the company. Company managers are expected to aid in the creation and maintenance of an employee's career development plan (Bidwell 2009). This career development plan highlights the set promotion path within the ranks of the company, allowing the permanent employee to further advance his/her career. Permanent employee career advancement positively affects the employees by increasing their pay, benefits and job responsibility and accordingly, their willingness and ability to positively contribute to company productivity (Bidwell 2009). Additionally, many companies, shipyards included, hold a thorough annual performance review process for each permanent worker and incentivize the permanent employee by providing performance-related bonuses at the end of each year. These bonuses vary by company but are typically between ten to twenty percent (Bidwell 2009).

Finally, drastically differing from permanent workers, Bidwell adds contingent workers may receive informal feedback with regards to their job performance, but any official counseling is conducted through their parent company. Additionally, contingent workers cannot be promoted within the company they are contracted to work for because they are not the company's permanent workforce. The contracted company's managers have little to no incentive to help the contingent workers with career development (Bidwell 2009).

E. WHAT IS THE EMPLOYEE COMPOSITION OF THE DEPARTMENT OF DEFENSE?

The DOD's workforce is responsible for completing a large number of different projects and tasks varying from warfighting jobs and responsibilities, to acquisition and maintenance jobs and positions. Public shipyards fall into this category as support and logistics roles. The varying tasks require different types of employees. For example, in a shipyard, welders, electricians, pipe fitters, and riggers all perform different tasks and are assigned to different shops in the shipyard, but the tasks combine together to complete the construction and maintenance of ships.

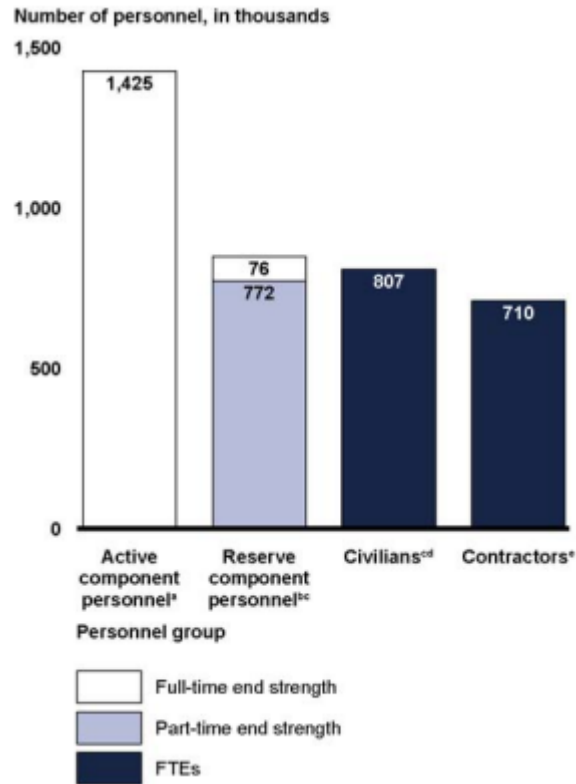
Currently, the DOD's employee architecture and shipyards' consists of three main components: military personnel (consisting of active duty, reservist and guard forces), government civilians, and government contractors (GAO 2013). The employment architecture very closely mimics the Dual Labor Market Theory (Mastracci and Thompson 2009). The DOD's mix of permanent employees and a core group of contracted or contingent employees is shown in 0

For the DOD at large, the military personnel, approximately 1.4 million strong in FY 2011, support the President of the United States and Congress in carrying out the essential military functions required by the United States from actual warfighting to the logistics and support needed to support the "boots on ground soldiers" (GAO 2013). In shipyards, however, the role of military personnel is slightly different. Military officers and senior enlisted members in shipyards are typically in management positions overseeing the work performed by government civilians or contractors. However, occasionally, in shipyards military personnel are used for their operational and technical expertise to physically perform maintenance or construction on ships.

In the DOD at large, DOD civilians support the military personnel and their families directly and indirectly by providing support activities such as logistical support, maintenance, intelligence, and cyber defense. Additionally, the DOD civilians augment the military personnel overseas, providing their technical expertise and knowledge on the front lines of the battlefield (GAO 2013). In 2011, there were approximately 807,000 full time equivalent (FTEs) government civilians (GAO 2013). In shipyards, DOD civilians

do not provide the same support as they do in the greater DOD. Instead, DOD civilians hold a variety of different jobs such as managers, welders, shipfitters, sheetmetal workers, electricians, carpenters, boilermakers, machinists, riggers, quality assurance auditors.

Finally, supplementing both the military and government civilian workforce, the DOD employs contractors. Typically in shipyards and the greater DOD, these contractors perform jobs similar to their government civilian counterparts. For fiscal year 2011, the DOD reportedly spent over \$145B on contracted services and employed approximately 710,000 contractor FTEs (GAO 2013). The breakdown for shipyard contractors is unavailable. The GAO explains the actual number of contracted employees is extremely difficult to measure because the DOD contracts services, not individuals. The contractor provider determines the number of contracted employees necessary to complete the job, not the government. The number of contracted employees in each public shipyard can vary between jobs and between service providers. The total number of DOD employees is represented graphically in 0



Notes:

^aActive component end strength includes Army, Navy, Marine Corps, and Air Force servicemembers as of the end of fiscal year 2011.

^bThe reserve component end strength includes the approximately 772,000 part-time and the approximately 76,000 full-time Army Reserve, Navy Reserve, Marine Corps Reserve, Air Force Reserve, Army National Guard and Air National Guard servicemembers in the selected reserve as of the end of fiscal year 2011. The reported reserve component end strength does not include the Individual Ready Reserve or the Inactive National Guard.

^cCivilian FTEs is an estimate of full time direct hires, indirect hires, and foreign nationals for fiscal year 2011. Foreign nationals account for about 49,000, or 6 percent of the civilian workforce.

^dDual status technicians are included in both the selected reserve part-time end strength and the civilian FTEs.

^eThe number of contractor FTEs is DOD's estimate based on data reported in its inventory of contracted services for fiscal year 2011.

Figure 1. DOD's Reported Number of Active Component End Strength, Reserve Component End Strength, Civilian Full Time Equivalent (FTE) (from GAO 2013)

The staffing composition of the federal government, including the DOD and the public shipyards, has been shifting over the few past decades. The FY 2002 President's Management Agenda (PMA) highlights the shifting mentality by issuing federal agencies the following order:

Agencies will determine their “core competencies” and decide whether to build internal capacity, or contract for services from the private sector. This will maximize agencies’ flexibility in getting the job done effectively and efficiently. (PMA 2002, 14)

This simple order directs agencies, shipyards included, to consider contracting, contingent employment, as well as standard employment when a new hire is needed, with the ultimate goal of completing the task at hand as efficiently as possible.

F. EMPLOYER BENEFITS AND DRAWBACKS OF A CONTINGENT WORKFORCE

The use of a contingent workforce allows a shipyard to remain agile to changing workload conditions. In many instances, the shipyard can quickly and efficiently hire employees as contractors or contingent workers and then subsequently downsize the workforce when a lapse of work occurs. Contingent worker’s termination ease increases the shipyard’s overall workforce numerical flexibility while reducing the fixed labor costs, although the overall cost of labor: the fixed labor and the variable (contingent) labor increases (Stirpe, Bonache, and Revilla 2014).

The contingent workforce provides the shipyards with numerical workforce flexibility in supplementing their permanent workforce. For example, if a large number of employees are taking vacation days simultaneously or sick leave unexpectedly, the shipyard could quickly and easily hire temporary replacements in the form of contingent workers (Paul and Townsend 1998). This ease of hire assumes a pre-existing relationship with the contingent workers’ hiring agency and a proven, routine use of finding quality contingent workers through that agency. If, however, the contingent worker’s hiring agency is not a part of the shipyard’s previous history, the overall length of the hiring process will increase because very few companies will hire additional labor without proper verification, validation, and quality control.

Additionally, a shipyard may use contingent workers to gain immediate access to KSAs not available in their current permanent workforce or that would be too expensive to develop in-house. Through a close examination a contingent worker’s resume, qualifications and previous work experience, the shipyard may hire a contingent worker

to meet the required KSAs immediately needed (David 2005). Hiring workers with a specific skill set would prove prudent if the KSAs are only needed for a specific project or task and not necessary on a full-time basis or if the skill set changes rapidly (David 2005).

By hiring a contingent worker possessing these KSAs, the shipyard could avoid the training or potential promotion costs associated with teaching a permanent worker the necessary skills for a one time needed project or task. Hiring these contingent workers would also help alleviate the overload of work experienced by the permanent workforce (Paul and Townsend 1998). However, employers must remain vigilant in treating these employees as contingent workers and not consultants that require adherence to a different set of rules and regulations.

Contingent workers also increase the permanent worker's job security in the shipyards. This increase in job security occurs by using the contingent workers as a shield for the company's permanent workforce from job loss due to market volatility (Arthur 2001). Firing flexibility is beneficial for the shipyard itself because the government is not subject to severance packages for the contingent workers and can better maintain a tight knit group of employees who have an increased loyalty to their shipyard due to their job security (Arthur 2001).

Contingent workers also allow the shipyard a means of screening new candidates for potential employment. By hiring a contingent worker, the shipyard could preview the worker's job performance and, if satisfied, extend an offer for permanent employment (Paul and Townsend 1998). This preview period eliminates some of the unknowns from the hiring process because the company already possesses firsthand knowledge of the type of work that contingent employee performs (Paul and Townsend 1998).

G. EMPLOYEE BENEFITS AND DRAWBACKS OF A CONTINGENT WORKFORCE

People work as contingent workers for a variety of reasons. Individuals may choose to work seasonal jobs or only perform their job for a set duration of time (for example, only through the Christmas holiday season). For instance, teachers or college students take contingent work as a means to fill gaps in their employment to earn supplemental income over the summer. Some individuals take contingent work because their base salary is higher than permanent workers (Arthur 2001). Other individuals hope contingent work will lead to full time employment or consider contingent work as a temporary fill between permanent jobs. Additionally, many contingent workers enjoy their independence and flexible working schedule. Some workers take contingent work to increase their skill level in a particular field or gain experience and exposure in a different work environment (Arthur 2001).

There are disadvantages to contingent work. If an individual is hoping to gain permanent employment eventually, they can become trapped in a contingent work cycle, moving from job to job, thus never gaining the job security they desire. Some workers may consider the lack of company benefits such as healthcare, paid vacation time, or retirement as a negative aspect of contingent work. Furthermore, contingent workers must remain current in the trades of their field of work because companies hire with the expectation of providing very little to no on the job training. If the field of study is constantly changing, staying abreast of the latest technology can not only be a large time commitment, but may also prove to be a financial burden for the contingent worker.

III. HUMAN CAPITAL MANAGEMENT

Before exploring human capital management and its relation to the contingent workforce in the DOD and in the shipbuilding industry, human capital and human capital management must first be discussed. Additionally, an analysis with respect to how human capital management is implemented across an organization and by which human capital management can be evaluated by the different types of framework is warranted.

A. WHAT IS HUMAN CAPITAL?

Although the term “human capital” is relatively new, the concept of human beings holding specific value has been prominent throughout economic theory for centuries. In 1691, Sir William Petty attempted to estimate the monetary value of a human being (Kiker 1966). Later, in 1853, William Farr attempted to calculate the present value of an individual’s net future earnings. Farr’s findings suggested that human beings and “human capital” should be taxed and regarded as capital (Kiker 1966). This tax would force humans to pay taxes on wealth they did not currently possess—a difficult concept to grasp, and one that would be unlikely to gain public support. In 1930, Louis Dublin and Alfred Lotka utilized an almost identical method to Farr’s for determining human capital (Kiker 1966).

Over centuries of evolution, human capital has developed a more universal and specific definition. Through various means such as training, education, proper management, and proper team placement, employees can develop specific KSAs which result in a type of capital (human capital) and increase their value to the shipyard. The term “capital” can be defined as “the “objects” and “processes” that generate value through energy, matter, material wealth, and information (EMMI) (Langford 2012). Energy is the capability to perform work; matter is anything comprised of energy or mass; material wealth is commonly thought of as money, but is also wealth represented through matter; and information is data within a particular context (Langford 2012). The aim of process integration is to improve the management of capital, assets, and operations, that is, increase the value of the organizational efforts. “Convenient measures

of process integration are operating efficiency and capital effectiveness” (Langford 2012, 135). The notion of considering human beings and their associated skills as capital, thus holding a monetary value, was used by nations throughout history to determine power, total cost of a war, and a person’s economic importance of (which aided courts to justly determine compensation for personal injury or death) (Kiker 1966).

Historically, the value of human beings was measured by two distinct methods: the cost-of-production and the capitalized-earnings procedures (Kiker 1966). The cost-of-production examines the real cost of “producing” a human being typically measured by the net maintenance of a human (Kiker 1966). The cost-of-production is not typically used due to the complex relationship between an item’s production cost and its economic value. The method followed today by economists when evaluating human capital is the capitalized-earnings procedure (Kiker 1966). The capitalized-earnings procedure examines the present value of a human’s future earnings and income (Kiker 1966). Yale University’s Robert Shiller defines human capital similar to the capitalized-earnings procedure and states that 72.1 percent of U.S. household income consists of human capital. Additionally, the National Center on Educational Quality of the Workforce (EQW) studied 3,100 U.S. workplaces and the relationship between education and productivity. The National Center EQW concluded productivity increased three fold when companies invested in human capital rather than investing in machinery or traditional capital financial instruments (bonds and short-term cash equivalent investments) (Stewart 1997).

The people in charge of building, maintaining, and operating systems used to defend the United States, also view the importance of managing human capital as essential to shipyard success (GAO 2013). Regardless of the complexity of the system being built, the organization responsible for the system can be treated as a complex system in its own right (Axelsson 2002). Properly structuring an engineering organization is both time consuming and exhaustive for the enterprise in terms of expended effort and expense. A strong driving component behind any organization is its people. An organization or company can be thought of as a system with its primary components being human resources and use of capital (Axelsson 2002).

B. WHAT IS HUMAN CAPITAL MANAGEMENT?

Although human capital management (HCM) by itself is not enough to guarantee increased performance, appropriate consideration to human capital is a vital step to assure an organization's mission and goals are achieved. Human capital management has evolved from personnel management and human resources management (U.S. Office of Personnel Management 2005). The term "human capital management" has come into being over the years evolving from traditional human resource programs and practices to better align human capital with the strategic business needs of the company. Titles, such as "Personnel Management Specialist" and "Human Resource Management Specialist," are now antiquated and replaced with "Human Capital Practitioner" (U.S. Office of Personnel Management 2005). The Human Capital Practitioner focuses attention on placing the right people in the right jobs at the right time. By strategically placing employees, work is performed more efficiently, and the results align better with the overall mission and strategy of the organization (U.S. Office of Personnel Management 2005).

The evolution of human capital management began with companies viewing employees as individuals, with a primary focus of minimizing costs. Personnel were seen as simply a means to complete a given task, correctly, without providing any individual input on how to better the task or process (U.S. Office of Personnel Management 2005). Companies then evolved to viewing an employee as a human resource. The human resource view placed the employee and the company in more of a business partnership. Instead of minimizing costs, companies looked to control costs and valued the employee's problem solving abilities as well as their operational abilities. Finally, human capital management places employees into a strategic partnership with the company. HCM shows the benefits of encouraging the companies to invest in their employees to receive a return on their investments to benefit the organization (U.S. Office of Personnel Management 2005). HCM focuses on strategic consulting and thinking from the employee. The employee is viewed as a company asset to educate, increase in value, and to help the company gain synergy and efficiency (U.S. Office of Personnel Management 2005). The evolution and cumulative nature of HCM is depicted in Figure 2.

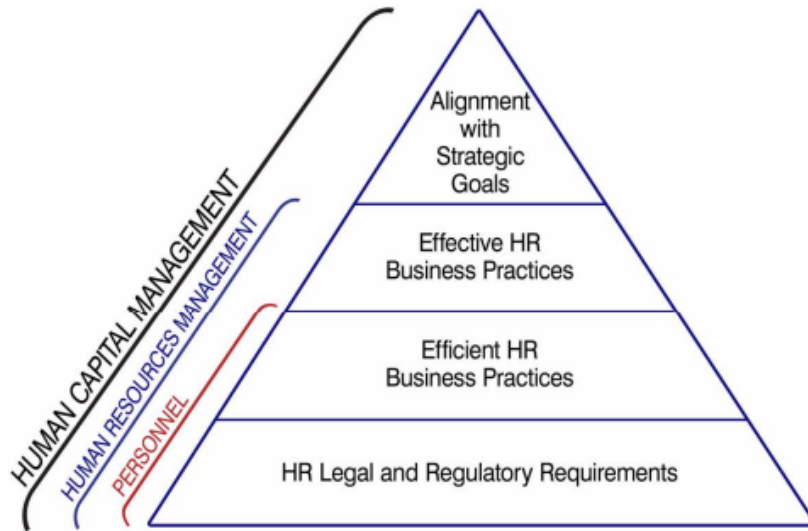


Figure 2. Cumulative Nature of Strategic Human Capital Management (from U.S. Office of Personnel Management 2005)

The definition of human capital management varies slightly depending on the author and context in which it is used. Langford, in a 2015 personal communication, describes HCM as:

An approach to leading and managing people. People are assets that can benefit from investment, sustainment, and life cycle analysis. How people learn, adapt, and work efficiently are embodied in their changes in competencies, how they manage their knowledge, and how they deal with organizational architecture and social behaviors.

Parten and Todd (2008, 8) in their thesis, “A Systems Engineering Approach to Address Human Capital Management Issues in the Shipbuilding Industry,” define HCM as “the act of developing, coordinating, and managing work force skills and competencies critical to an organization’s ability to perform its mission.”

Although HCM seems intuitive, until the late 1990s, its strategic value was largely overlooked by both the federal government and the private industry who viewed people as a means to cut or minimize costs instead of as a valuable asset (GAO 2003). In GAO 2000, *Human Capital: Managing Human Capital in the 21st Century*, federal employees were encouraged to be viewed as an asset to be valued and not a cost to be cut. Additionally, the GAO recognized that strategic HCM was critical to the success of

an organization and to optimize success, policies and practices must be designated, implemented and assessed through the organization to ensure they correspond to the mission and goals of the organization (GAO 2000). In 2002, the GAO further stated that for federal agencies, shipyards included:

People are an agency's most important organizational asset. An organization's people define its character, affect its capacity to perform, and represent the knowledge-base of the organization. As such, effective strategic human capital management approaches serve as the cornerstone of any serious change management initiative. (4)

The GAO noted that the human capital problem in the federal government does not lie with the employees, but rather that the management of human capital has no consistent strategic approach (GAO 2002). The GAO's insight demonstrates the essential need for human capital to be properly managed, structured, and implemented throughout an organization.

In shipyards, managing the workforce connected with periodic tasks and an ever changing workload can prove difficult due to multiple factors. For example, the March 2013 Pearl Harbor Naval Shipyard New Employee Reference Guide shows Pearl Harbor has 16 different departments and organizations shown in Figure 3.

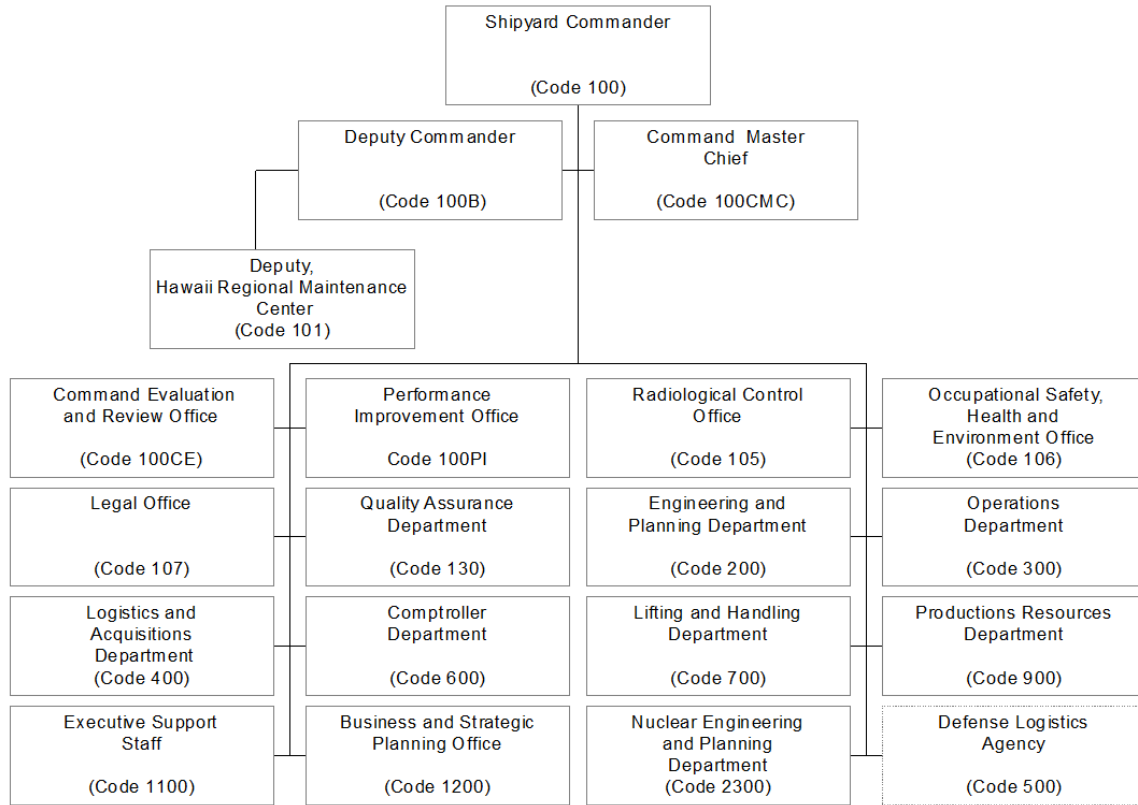


Figure 3. High-Level View of Pearl Harbor Naval Shipyard Organizational Architecture (from PHNSY 2013)

Each department acts alone to perform specific tasks for the shipyard, aiding in the overall success or failure of the ship availability. This organizational architecture reinforces an approach to managing workers that does not favor the spirit of human capital but rather on a very outdated interpretation of employees who are focused on performing the work at hand. For example, Pearl Harbor’s New Employee Reference Guide stipulates responsibilities of the Lifting and Handling Department (Code 700) include “all technical planning, maintenance, operation, training, inspection, testing, and certification of cranes (weight lifting), rigging (weight handling), and Special Purpose Services Weight Handling Equipment” (PHNSY 2013, 38). Additionally, all truck drivers, forklift, and vehicle operators and any other operator for material handling or automotive equipment are the responsibility of Code 700. If any rigging services are needed, Code 700 provides the manpower. Delays can occur, for example, if rigging services are required simultaneously for multiple different tasks and the shop can only

service one task at a time. These delays are a result of poorly designed shipyard architecture.

Similar to Code 700, period tasks can occur in PHNSY's Code 900 Production and Resources Development. Code 900 consists of six main shops each comprised of a variety of different trades used to accomplish ship availabilities. For instance, the structural shop, Code 920, consists of welders, shipfitters and sheet metal workers (PHNSY 2013). The majority of ships at some point in their availability will require some services from Code 920. If the tasks and workload are not properly managed, schedule delay and cost overruns due to overtime work can easily occur. The same principle can be applied to the mechanical, electrical, pipe, coating and services, and production, facility, and equipment management shops of Code 900.

In contrast, a system of systems perspective posits that human capital is best used in concert with the right people, at the right place, at the right time. As a start, the concept of an integrated project team (IPT) approach deals with the mechanistic details of interaction. Policies, procedures, processes, and funding facilitate an enlightened view of workers as human capital. The workers' tasks are integrated to achieve an efficient partnership between the workers assigned to a particular work group. As the number of tasks increases due to increases in throughputs of availabilities, the work groups interact, are cross trained, and vie for efficiency advantages to show their prowess and capability. Management of human capital helps build team unity and camaraderie.

In addition to tasks and workload experienced by the shipyard workers, the varying size and composition of the fleet and the associated maintenance infrastructure is a major influence on the workload experienced by the workers (Riposo et al. 2008). For example, email data provided by NSWC Dahlgren Division: W11 Warfare Analysis Force Structure and Analysis Model database shows that in 1964, the U.S. fleet consisted of 502 ships—consisting of 24 aircraft carriers, 231 surface combatants, 66 submarines, 34 amphibious ships, and 147 auxiliary and other combatants. In 2014, the U.S. fleet consisted of 257 ships consisting of 10 aircraft carriers, 99 surface combatants, 73 submarines, 31 amphibious ships, and 44 auxiliary and other combatants. In 50 years, the

size of the fleet was reduced by nearly half. Figure 4 and Figure 5 show the total fleet inventory and the inventory breakdown by ship class from 1950 until 2014.

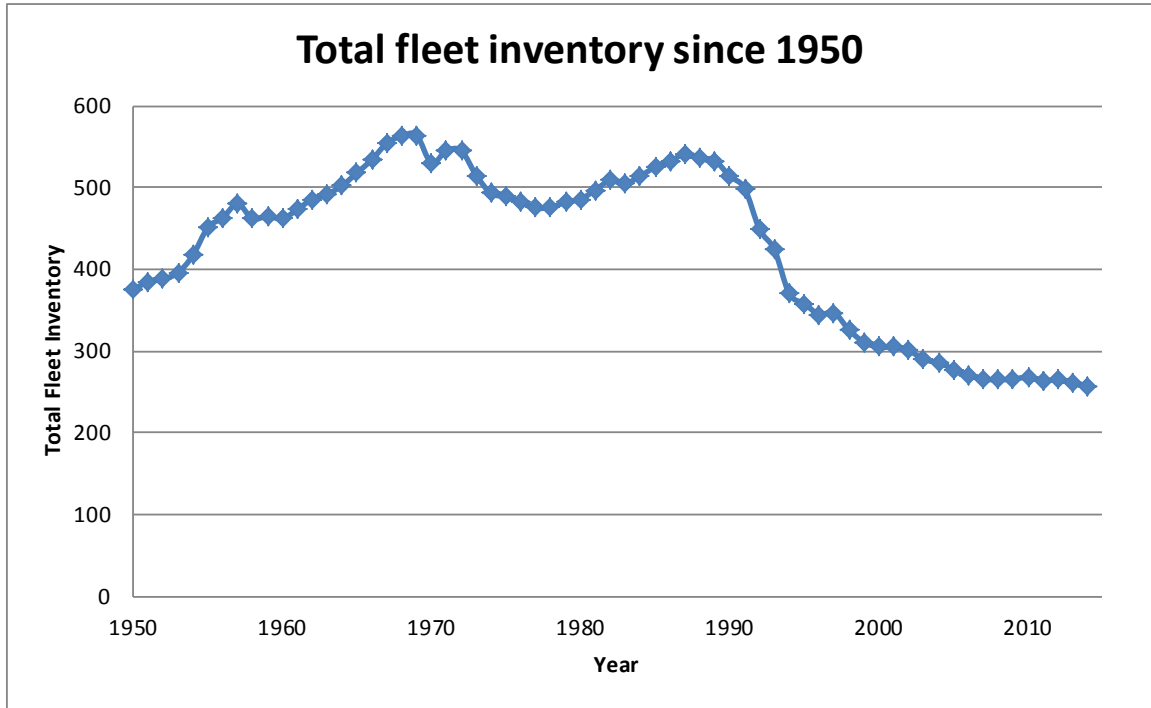


Figure 4. Total U.S. Fleet Inventory from 1950–2014

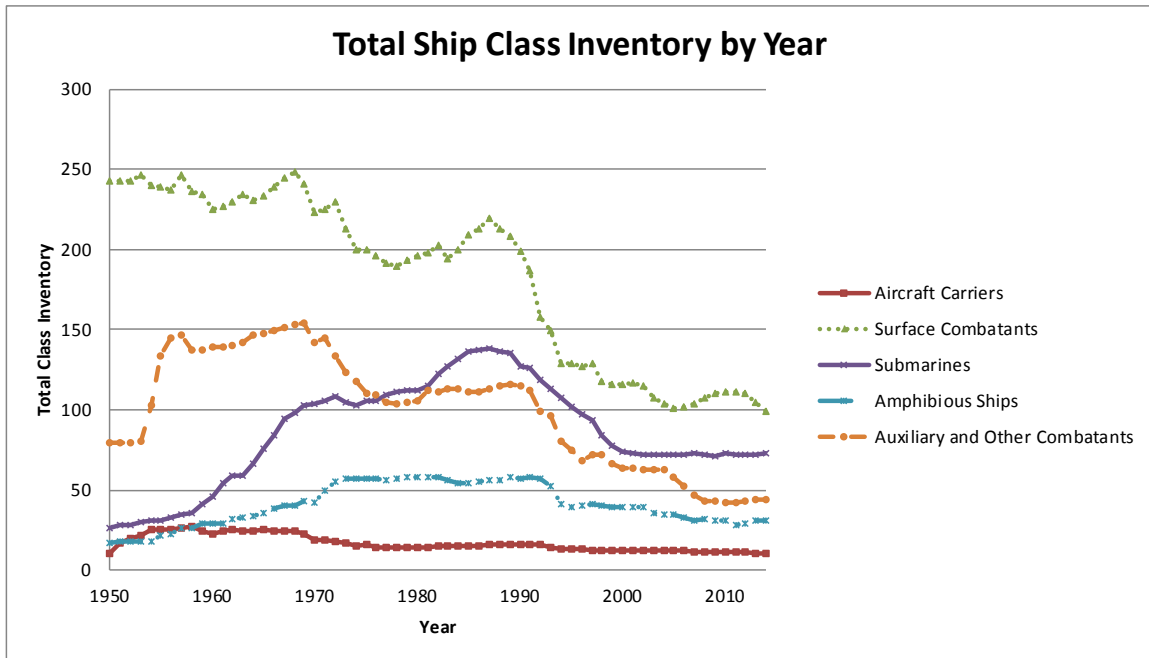


Figure 5. Total Ship Class Inventory from 1950–2014

The steady decline in the total ship inventory and the changing composition of the fleet caused a reduction in the total workload experienced by the shipyards which resulted in a reduction in industrial facilities (Riposo et al. 2008). While the reduction in force is managed according to contract regulations and union rules, human capital management offers both the principles to follow as well as the best practices to maintain the team unity and camaraderie necessary for efficiency and effectiveness as a workforce. The smaller ship inventory and the different classes of ships cause variation and uncertainty in the type and amount of work experienced by the public shipyards (Riposo et al. 2008). Depending on the class of ship, the size of the availability can drastically vary from a few thousand man-days to a few hundred thousand man-days. Figure 6 shows the notional depot-level workloads and duration for different ship types and maintenance types. Due to the wide variation in availability size, the shipyard experiences “peaks” and “valleys” in their workload. These “peaks” and “valleys” for the demand of skilled workers cause the workload to severely vary (Riposo et al. 2008).

Ship Type/Availability Type	Workload (thousands of man-days)	Duration (months)
Nuclear aircraft carrier		
PIA	150–200	6.0
DPIA	260–360	10.5
Nuclear submarine		
DSRA/ERP	22–80	2.0–8.0
Overhaul	145–200	13.0–16.0
Refuel	300–340	16.0–27.0
Amphibious ship		
Docking	80–140	4.0–6.0
Pier-side	15–25	2.0–3.0
Surface combatant		
Docking	8–50	2.0–12.0
Pier-side	3–8	2.0–4.5

Figure 6. Notional Depot-Level Work Package for Naval Ships
(from Riposo et al. 2008)

Additionally, although ships may be classified as the same availability type at the beginning of the availability, each ship has a different material readiness condition, may need different upgrades or modernization packages, and may have different funding levels (Riposo et al. 2008). The combination of these factors can drastically change the actual work performed on the ship, altering the workload for the workforce and therefore the number of workers. The combination of these factors demonstrates the incredibly difficult nature of managing the workforce and work level in a public shipyard (Riposo et al. 2008).

C. STRATEGIC IMPLICATIONS OF HUMAN CAPITAL

The goal of human capital management is to apply more of what workers learn and know. In order to accomplish this goal, shipyards need to create opportunities for employee’s private knowledge to be made public and their unspoken, implicit knowledge to be made explicit (Stewart 1997). In the GAO 2000, *Human Capital: Managing Human Capital in the 21st Century*, the GAO proposed 10 human capital principles taken from

the nine private sector organizations evaluated. Each goal strives to support directly the achievement of a specific mission, goal or core value of the organization.

1. Treat human capital management as being fundamental to strategic business management. Integrate human capital considerations when identifying the mission, strategic goals, and core values of the organization as well as when designing and implementing operational policies and practices.
2. Integrate human capital functional staff into management teams. Include human capital leaders as full members of the top management team rather than isolating them to provide after-the-fact support. Expand the strategic role of human capital staff beyond that of providing traditional personnel administration services.
3. Leverage the internal human capital function with external expertise. Supplement internal human capital staff's knowledge and skills by seeking outside expertise from consultants, professional associations, and other organizations, as needed.
4. Hire, develop, and sustain leaders according to leadership characteristics identified as essential to achieving specific missions and goals. Identify the leadership traits needed to achieve high performance of mission and goals, and build and sustain the organization's pool of leaders through recruiting, hiring, development, retention, and succession policies and practices targeted at producing leaders with the identified characteristics.
5. Communicate a shared vision that all employees, working as one team, can strive to accomplish. Promote a common understanding of the mission, strategic goals, and core values that all employees are directed to work as a team to achieve. Create a line-of-sight between individual contributions and the organization's performance and results.
6. Hire, develop, and retain employees according to competencies. Identify the competencies—knowledge, skills, abilities, and behaviors— needed to achieve high performance of mission and goals, and build and sustain the organization's talent pool through recruiting, hiring, development, and retention policies and practices targeted at building and sustaining those competencies.
7. Use performance management systems, including pay and other meaningful incentives, to link performance to results. Provide incentives and hold employees accountable for contributing to the achievement of mission and goals. Reward those employees who meet or exceed clearly defined and transparent standards of high performance.
8. Support and reward teams to achieve high performance. Foster a culture in which individuals interact and support and learn from each other as a means of contributing to the high performance of their peers, units, and the organization as

- a whole. Bring together the right people with the right competencies to achieve high performance as a result, rather than in spite, of the organizational structure.
9. Integrate employee input into the design and implementation of human capital policies and practices. Incorporate the first-hand knowledge and insights of employees and employee groups to develop responsive human capital policies and practices. Empower employees by making them stakeholders in the development of solutions and new methods of promoting and achieving high performance of organizational missions and goals.
 10. Measure the effectiveness of human capital policies and practices. Evaluate and make fact-based decisions on whether human capital policies and practices support high performance of mission and goals. Identify the performance return on human capital investments. (21)

By employing the ten human capital principles, the effectiveness of human capital management practice can be measured to evaluate the degree to which management is effectively supporting and facilitating the organizational mission, values and goals (GAO 2000).

Without attention into the workforce through the lens of human capital management, the performance of tasks and the structure of operations does not benefit from the enlightened workforce. A sound test for a highly valued workforce (i.e., high value of human capital) is that the workforce feels deeply involved in their work. Secondary tests of the value of the workforce human capital center on low levels of sick leave and high levels of having arranged for a successor to carry on with the work. In other words, the workforce believes that their work tasks are so important as to merit a back-up plan in case of absence from work. The reciprocal arrangement is for the employer organization to show they value human capital by accommodating flexible work schedules, empowering workers to respect their personal time, and encouraging behaviors that engender trust, reliability, and commitment to the work. The inspiration for carrying the concept of human capital to its logical quid pro quo between enterprise and workers is to think of both as being the same. The inspiration for the same rights, same interests, and same outcomes derives from various authors, most notably Ricardo Semler in his 2004 book, *The Seven-Day Weekend*.

Workers who take greater than the average amount of sick leave are a telling early indicator of low-levels of human capital. A 2012 study of shipyard workers in Greece indicates that examining sick-leave is crucial to understanding a worker's capacity to work and overall health status. Sick-leave is not only taken for health related illness. Psychosocial factors and coping behaviors contribute to an employee's propensity to utilize sick-leave. The study showed that sick leave accounted for 1% of the employment time lost in the Greek shipyards (Alexopoulos et al. 2012). Shipyard employees took an average number of sick-leave days ranging from 4.6 to 8.7 per year (Alexopoulos et al. 2012). Additionally, the sick-leave rate, the total number of sick-days per the number of employees and the number of working days, also called the sickness absenteeism rate was found to vary between 2% and 3.7% (Alexopoulos et al. 2012). The Greek study illustrates the results of the employer's frustration of loss of work days taken through the use of sick leave.

The Minnesota Department of Health's Center for Health Equality found numerous benefits for employees and companies who offer paid sick leave. The benefit of employee sick leave is well known and accepted by employers, so they offer paid sick leave. However, once the benefit is offered, employees take advantage of the benefit to deal with the mental distress associated with their job and work. When companies offer paid sick leave, their employees are healthier, use less sick time, need less health care, and their children perform better in school (Ehlinger 2015). Mothers with paid sick leave have improved mental and physical health, receive better prenatal and postnatal medical care, breastfeed for longer, and have an overall increase in mother-child bonding (Ehlinger 2015). Additionally, employees with paid sick leave have an increased probability of scheduling and keeping preventative care appointments, recover quicker from illness, and prevent the spread of disease in the workplace if sick leave is properly utilized (Ehlinger 2015).

Public U.S. shipyards workers earn sick leave at a rate of four hours per pay period, equating to 13 days a year. Sick leave is accrued at this rate regardless of years in service. The sick leave is typically used for illness, injury, and pregnancy as well as for medical, optical, or dental appointments (PHNSY 2013). Data provided electronically by

Naval Sea Systems Command, NAVSEA, 04 in April 2015 of Puget Sound Naval Shipyard between 2007 and 2014 showed the average sick leave days taken per employee varied between 10.9 and 12.5 days per year. The use of paid sick leave indicates the workforce at the shipyard should be healthy both physically and emotionally.

D. CORE COMPETENCIES AND COMPETITIVE ADVANTAGE

Competencies are a “set of behaviors critical to successful work accomplishments. They describe what the employees know, what they do, how they do it and translate into effective on-the-job performance” (GAO 2004, 2). The United States Coast Guard defines competencies slightly differently as, “A collection of tasks with the associated skills, knowledge, abilities, and wherewithal (tools, methods, information, doctrine, procedures, and materials, for example) needed to perform the tasks to a predetermined, measurable, performance standard. The tasks are usually related as parts of a larger process in support of or contributing to the goals of the organization, unit, or workgroup” (Kramer 2004). The DOD defines competency as “an observable, measurable pattern of knowledge, skills, abilities, behaviors, and other characteristics that an individual needs to perform work roles or occupational functions successfully” (DOD 2009). Each definition of competency highlights factors that contribute to the employee’s value as human capital. Therefore, competencies contribute to employee’s value. However, it is important to note that one does not need to be an employee to have value as human capital.

Competencies are the connection between an employee’s KSAs and the mission requirements of an organization. Competencies exist at all layers of an organization. The goal of competencies is to set a universal language to convey job requirements accurately to prospective candidates, to institutionalize training requirements to training developers and educational institutions, and finally to aid in career development and personal expectations management for workers (Kramer 2004). The common language set by competencies provides better alignment between the overall mission and needs of the organization and the individual’s performance and expectations (Kramer 2004). This alignment provides the necessary link between the overarching mission, employee

positions held, jobs available, and training required-the basis for human capital management and planning. The proper management of competencies provides a clear definition of individual responsibilities and allows the employees' KSAs to be monitored and measured. Competency management can also provide career advancement mentorship and job opportunity information (Kramer 2004).

Similar to the broad definition of a competency, the competencies themselves should be generic enough to be used across multiple different companies or agencies within civilian or government sector (Kramer 2004). With few exceptions, competencies are not designed to be so narrowly defined and unique that they only fit one particular location, position, or job. Such unique competency definitions would cause the sheer number of competencies created to become unmanageable, thus quickly losing usefulness. Although competencies may initially sound simple, in reality quantifying them can be relatively complex (Kramer 2004).

The DOD further expands competencies into six separate categories: leading change, leading people, results driven, business acumen, building coalitions, and enterprise-wide perspective. Figure 7 provides a description and the components of each core competency. Additionally, the DOD has a civilian leader development continuum. Figure 8 shows the development from leading teams, to leading people, to leading organizations and programs, to finally leading institutions. The developmental framework along with the development continuum provides a roadmap for the calculated career development of DOD civilian leaders below the executive level (DOD 2009). Competencies can also be thought of as factors that add to the overall capital worth of an employee.

LEADING CHANGE	LEADING PEOPLE	RESULTS DRIVEN	BUSINESS ACUMEN	BUILDING COALITIONS	ENTERPRISE-WIDE PERSPECTIVE (TECHNICAL)
DESCRIPTIONS OF CORE COMPETENCIES					
Involves the ability to bring about strategic change, both within and outside the organization, to meet organizational goals. Inherent to this competency is the ability to establish an organizational vision and to implement it in a continuously changing and highly ambiguous environment. Balances change with continuity and addresses resistance.	Involves the ability to lead and inspire a multi-sector group (not only employees (civilian and military), but also other Government agency personnel at the Federal, State, and local levels, as well as contractors and grantees) toward meeting the organization's vision, mission, and goals. Inherent to this competency is the ability to provide an inclusive workplace that fosters the motivation and development of others and facilitates effective delegation, empowerment, personal sacrifice, and risk for the good of the mission, as well as trust, confidence, cooperation, and teamwork, and supports constructive resolution of conflicts.	Involves the ability to meet organizational goals and customer expectations. Inherent to this competency is stewardship of resources, the ability to make decisions that produce high-quality results by applying technical knowledge, analyzing problems, and calculating risks.	Involves the ability to manage human, financial, and information resources strategically. Inherent to this competency is the ability to devise solutions with an understanding of how to impact business results by making connections between actions or performance and organizational goals or results, as well as external pressure points.	Involves the ability to build coalitions internally and with other Federal agencies, State and local Governments, nonprofit and private sector organizations, foreign governments, or international organizations to achieve common goals.	Involves a broad point of view of the DoD mission and an understanding of individual or organizational responsibilities in relation to the larger DoD strategic priorities. The perspective is shaped by experience and education and characterized by a strategic, top-level focus on broad requirements, joint experiences, fusion of information, collaboration, and vertical and horizontal integration of information.
COMPONENTS OF CORE COMPETENCIES					
<ul style="list-style-type: none"> • Creativity and Innovation • External Awareness • Strategic Thinking • Vision • Flexibility • Resilience 	<ul style="list-style-type: none"> • Conflict Management • Leveraging Diversity • Developing Others • Team Building 	<ul style="list-style-type: none"> • Accountability • Decisiveness • Entrepreneurship • Customer Service • Problem Solving • Technical Credibility 	<ul style="list-style-type: none"> • Financial Management • Human Capital Management • Technology Management • Computer Literacy 	<ul style="list-style-type: none"> • Political Savvy • Influencing and Negotiating • Partnering 	<ul style="list-style-type: none"> • Joint Perspective <ul style="list-style-type: none"> - Mission Orientation - DoD Mission and Culture - DoD Corporate Perspective - National Defense Integration - Global Perspective • National Security <ul style="list-style-type: none"> - Foundation - Environment - Strategy
FUNDAMENTAL COMPETENCIES: These competencies are the foundation for success in each of the core competencies. <ul style="list-style-type: none"> <li style="width: 33%;">• Interpersonal Skills <li style="width: 33%;">• Written Communication <li style="width: 33%;">• Continual Learning <li style="width: 33%;">• Integrity and Honesty <li style="width: 33%;">• Oral Communication <li style="width: 33%;">• Public Service Motivation 					

Figure 7. DOD Civilian Leader Development Framework: Executive Core, Technical Core, and Fundamental Competencies (from DOD 2009)

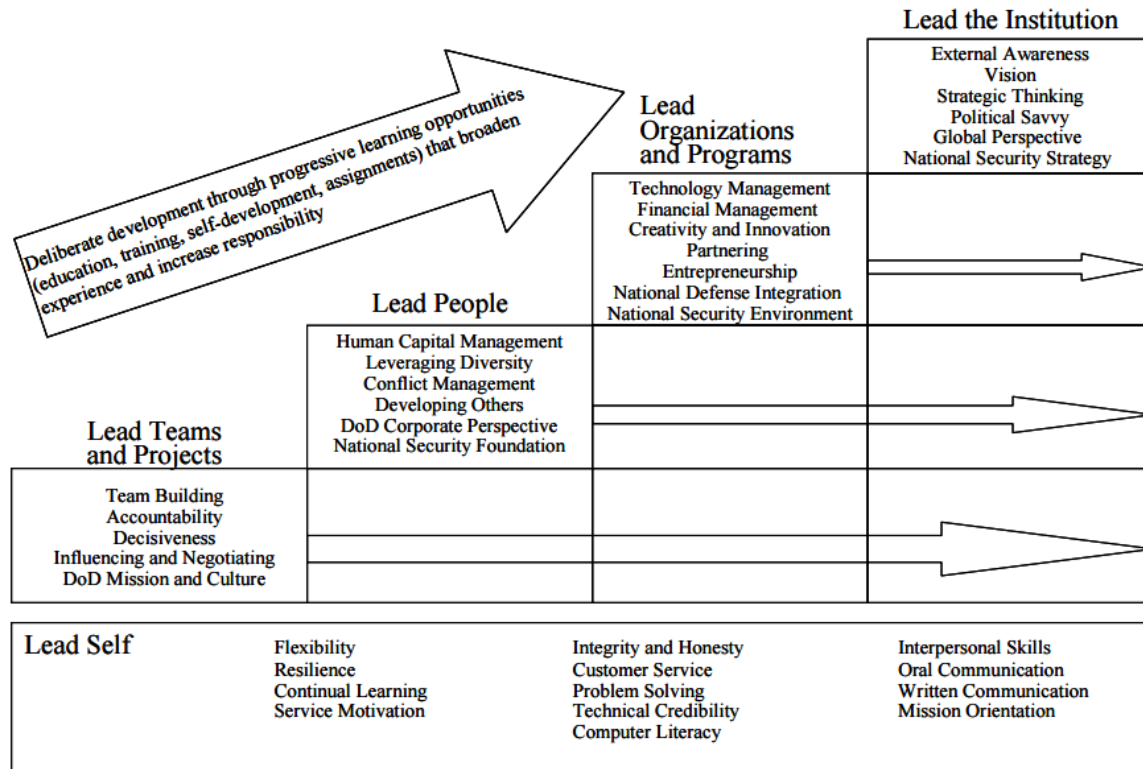


Figure 8. DOD Civilian Leader Development Continuum (from DOD 2009)

In general, the skills from which the DOD derived their competencies come in three forms: commodity skills, leveraged skills, and proprietary skills (Parten and Todd 2008). These three competencies are required for any task, process, or business. Commodity skills are not specifically tied to one business (Stewart 1997). Commodity skills are easily acquired and can be thought of as universally valued by most businesses. For the shipbuilding industry, technical commodity skills include “drafting and tool-related experience and fundamental engineering sciences knowledge, such as computer aided design and drafting (CAD), finite element analysis and mechanical and electrical engineering” (Parten and Todd 2008, 15). Leveraged skills are thought of as industry specific skills but not company specific skills although some companies may value leveraged skills more than other companies (Stewart 1997). In the shipbuilding industry, leveraged skills are the “industry specific skills such as naval architecture and marine engineering (NA&ME), and radar and weapons systems integration,” (Parten and Todd 2008, 15). Lastly, organizations build their companies around proprietary skills, which

are company specific. These special skills distinguish a company from its competitors. Proprietary skills are shown in patents, copyrights, and intellectual property (Stewart 1997). Proprietary skills in the shipbuilding industry include “specific manufacturing processes (such as composite structures design, unique welding procedures) and analytical techniques related to stealth characteristics, hydrodynamics, and electrical propulsion” (Parten and Todd 2008, 15).

E. HUMAN CAPITAL MANAGEMENT ARCHITECTURES AND PROCESSES

Varying viewpoints exist on how to best manage human capital. One view suggests that by asking a series of five questions: how well does the business manage: talent, “well-being proposition,” people risks, leadership roles, and data, a company can better manage their human capital (Reddy 2011). Managing talent encompasses recruiting top performers into the organization, and also creating a team of talented individuals, each team being able to showcase team members’ strengths. Managing the “well-being proposition” encourages the employer to improve both the physical and psychological health of the employee by creating an overall healthy working environment (Reddy 2011).

Managing people risk may be the most difficult but important managerial task. People risk includes, but is not limited, to poor job attendance, conflict between coworkers, dishonest acts, poor employee health and lifestyle choices, stress induced mistakes, and poor decisions (Reddy 2011). Employees’ behavior directly influences every facet of the company. Employee skills, motivation, and teamwork ability can be impacted negatively by poor employee risk management. A manager’s ability to change his or her leadership style, to match the needs of each employee, aids in the effective management of human capital (Reddy 2011). Finally, management’s ability to use and interpret human capital data correctly can aid managers in better utilization of their human capital (Reddy 2011).

Not every employee of a company is considered a high value asset. In fact, only a small, select number of employees are considered a high value addition of human capital. The idea of characterizing the workforce can be shown by breaking a company's workforce into four distinct categories, shown in Figure 9, suggesting that companies have both low value and high value employees. Although the human capital contribution of a low value employee is minor, it is still value added to the company.

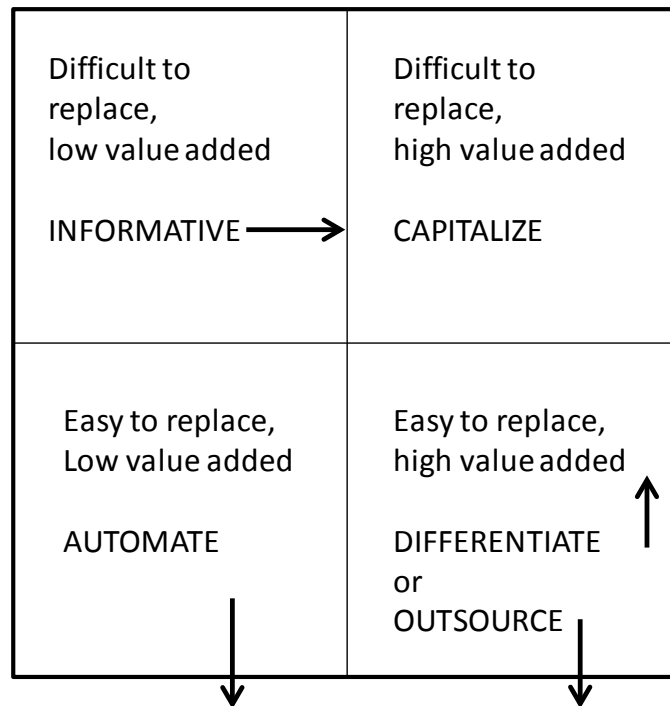


Figure 9. Stewart's Four-Quadrant Human Capital Model (after Stewart 1997)

The lower left quadrant embodies the unskilled and semiskilled labor for a company- not human capital (for example: unskilled or semiskilled assembly line workers). Although the organization may require many unskilled laborers to complete a task, the success of the organization does not reside within the individual unskilled worker, rather the unskilled workforce as a whole (Stewart 1997). In some cases, depending on the cost of the replacement of the unskilled job, unskilled jobs may be ideal to automate, depending on the life cycle costs of automation. Automating the work whenever possible may save time and money (training costs and salary costs). However,

it is not the skill level that should drive automation with robots, for example. If used correctly, that unskilled worker provides a means of communication and “glue” that helps bind the company policy and vision throughout the organization (Langford 2015, personal communication).

The upper left quadrant houses employees whose work is important to daily company operations (for example: quality assurance positions, staff jobs, experienced secretaries, and skilled factory workers) but to the consumer, these positions do not increase their profit (Stewart 1997). Ideally, companies want to “informate” or change the work to add more valued information so the employer and the customer see the benefit in these positions (Stewart 1997). By changing the job to be more informative, the employee transitions from acting simply as a labor cost to holding human capital for the company. An example of this job transition would be to change the quality assurance positions so they are used to prevent errors, not simply identify errors after the fact, which would save the company both time and money (Stewart 1997).

The lower right quadrant represents employees who complete work that customers value highly; from the company’s perspective, these employees are easily replaceable or interchangeable (Stewart 1997). A good software security engineer is an example of this type of employee. For these employees, the company has two options. First, companies can outsource the work. By outsourcing, the company is freed from paying for non-proprietary labor and can focus costs on labor that will increase bottom-line profit. Conversely, a company can turn a generic aspect of the work into something truly company unique. This way a company can brand itself as exclusive and holding proprietary knowledge and charge the customer an increased premium (Stewart 1997).

Finally, a company’s human capital is captured in the upper right quadrant. Employees here have the KSAs that allow them to fulfill irreplaceable positions within the company that are valued not only by the company but by the customers (Stewart 1997). These employees and their skill sets are an asset to the company. The employees can hold any position in the company (for example: welders, shipfitters, project managers) but their value comes from how they perform their job and how valuable their position is to the overall success of the project.

IV. U.S. NAVY PUBLIC SHIPYARDS

Every naval ship requires maintenance whether corrective, preventative, or an upgrade throughout its life cycle. Ship's crew is able to provide some of the necessary support required to complete basic repair and maintenance (Riposo et al. 2008). However, ship's crew lacks the available resources, specialized knowledge, and time to complete the larger tasks and maintenance required by the ship. This more-involved maintenance, referred to as depot-level maintenance, is typically performed at a shipyard specializing in the repair required. Depot-level maintenance is completed by both the public and private shipyards in the United States (Riposo et al. 2008).

A. THE FOUR PUBLIC SHIPYARDS

The U.S. Navy's four public shipyards—Norfolk Naval Shipyard (NNSY or Norfolk), Pearl Harbor Naval Shipyard (PHNSY or Pearl Harbor), Portsmouth Naval Shipyard (PNSY or Portsmouth), and Puget Sound Naval Shipyard (PSNSY or Puget Sound)—are critical in maintaining fleet readiness and supporting ongoing operations worldwide. The public shipyards provide depot-level maintenance to the Fleet as well as performing “alterations, refit and restoration, decommissioning of nuclear assets, design services, support services, and other planning functions” (Riposo et al. 2008, 3). Additionally, the public shipyards support the Fleet by providing “voyage (or underway) repairs, oversight of private-sector contracts, component repair of special equipment, and other intermediate-level tasks” (Riposo et al. 2008, 3).

Required by federal law, each shipyard maintains the required critical skills and facilities necessary to complete depot-level maintenance. The amount of depot-level maintenance performed can be determined by the workload of a shipyard. The average annual workload of each shipyard from 2007–2013 is shown in Figure 10. Between 2007 and 2013, Puget Sound had the largest average annual workload followed by Norfolk, the Pearl Harbor and finally Portsmouth.

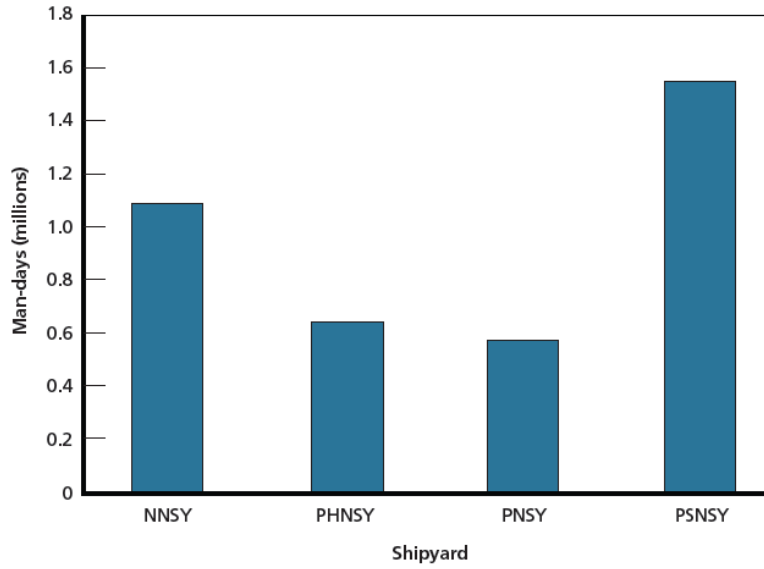


Figure 10. Average Annual Workload, 2007–2013 (from Riposo et al. 2008)

Figure 10 shows that each shipyard is unique in the workload size and workload compositions. The four different shipyards are described in more detail in the following sections.

1. Norfolk Naval Shipyard

NNSY is located in Portsmouth, Virginia next to a major fleet concentration area (see Figure 11), which is homeport to more than 60 ships (Riposo et al. 2008).



Figure 11. Norfolk Naval Shipyard (from U.S. Navy 2015a)

NNSY is the largest public shipyard on the East coast and considered one of the largest shipyards in the world. NNSY is the United States' oldest and largest industrial facility employing approximately 8500 military and civilian personnel (U.S. Navy 2015a). NNSY is the only East coast public shipyard capable of dry docking a nuclear aircraft carrier as well supporting all classes of ships (Riposo et al. 2008).

NNSY is capable of performing construction, conversion, repair, overhaul, alteration, dry docking, outfitting, and modernization on all ships and submarines in the U.S. fleet. NNSY has 14 major production shops with jobs hailing from the Shipfitter Shop, to the Woodworking Shop, to the Riggers and Laborers Shop (U.S. Navy 2015a). The Secretary of the Navy assigned NNSY's mission as follows:

- provide logistic support for assigned ships and service craft
- perform authorized work in connection with construction, conversion, overhaul, repair, alteration, dry docking, and outfitting of ships and craft, as assigned
- perform manufacturing, research, development and test work, as assigned
- provide services and material to other activities and units, as directed by competent authority. (U.S. Navy 2015b)

In 2006, NNSY executed 1.4 million man-days worth of work and projected between 0.9 million and 1.3 million man-days worth of work each subsequent year through 2013 (Riposo et al. 2008).

2. Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility

PHNSY is located in Pearl Harbor, Hawaii (see Figure 12) and home to the Regional Maintenance Center (RMC) specializing in repair and maintenance for ships located in Hawaii (U.S. Navy 2015c).



Figure 12. Pearl Harbor Naval Shipyard (from U.S. Navy 2015c)

Due to Hawaii's strategic position in the Pacific, PHNSY provides emergency repair and maintenance for ships stationed at or deployed in the Pacific. Primarily, PHNSY supports Los Angeles class submarines, cruisers, destroyers, and frigates (Riposo et al. 2008). In emergencies, PHNSY can dry dock a nuclear aircraft carrier, but it is not equipped to perform routine maintenance on carriers (Riposo et al. 2008).

PHNSY is Hawaii's largest industrial employer employing approximately 4,500 civilian and nearly 500 uniformed military personnel (U.S. Navy 2015c). Of the 4,500 civilians, approximately 1,400 work in General Service including over 500 mechanical, civil, electrical, structural, and nuclear engineers (U.S. Navy 2015c). Additionally, PHNSY employs over 2,600 Wage Grade employees (U.S. Navy 2015c). The Wage Grade employees are blue-collar employees holding craft, trade, and laboring positions

(U.S. Office of Personnel Management 2015). Wage Grade employees are paid on an hourly basis (U.S. Office of Personnel Management 2015). In 2006, PHNSY executed approximately 700,000 man-days of work and an estimate provided by NAVSEA 04 in 2008 projects between 620,000 and 660,000 man-days annual workload for each subsequent year until 2013 (Riposo et al. 2008).

3. Portsmouth Naval Shipyard

PNSY in Kittery, Maine (see Figure 13) is located on Seavey Island, a federally owned island at the mouth of the Piscataqua River, and includes over 297 acres for the base and military housing (U.S. Navy 2015d).



Figure 13. Portsmouth Naval Shipyard (from U.S. Navy 2015d)

PNSY employs approximately 4,700 civilians and 100 military personnel (U.S. Navy 2015d). PNSY's primary mission is to overhaul, repair, and modernize all active classes of submarines. The three active dry docks allow for a full spectrum of in-house support for the Los Angeles, Ohio, and Virginia class submarines in the U.S. Navy (U.S. Navy 2015d).

In 2005, the DOD issued a recommendation to close PNSY but was overturned by the 2005 Base Realignment and Closure (BRAC) Commission. Due to the near closure,

PNSY experienced some unforeseen losses in the workforce. Despite workforce reduction, in 2006 PNSY executed approximately 700,000 man-days of work (Riposo et al. 2008). In 2008, NAVSEA 04 estimated that between 480,000 man-days and 630,000 man days of annual work would be carried out until 2013 (Riposo et al. 2008).

4. Puget Sound Naval Shipyard

PSNS (see Figure 14) is unique in that it comprises six different locations: Bremerton, Bangor, Everett, San Diego, Boston, and Japan.



Figure 14. Puget Sound Naval Shipyard: Everett, Washington (from U.S. Navy 2015e)

The Bremerton site is located in Bremerton, Washington and is the largest U.S. Naval shore facility in the Pacific Northwest (U.S. Navy 2015e). Additionally, Bremerton is one of Washington State's largest industrial installations (U.S. Navy 2015e). Currently, PSNS is the only shipyard capable of performing nuclear defueling before decommissioning (Riposo et al. 2008).

The other detachments of PSNS are capable of supporting a wide variety of work on various different platforms (Riposo et al. 2008). The Bangor site is the largest command at Naval Base Kitsap and located near Silverdale, Washington (U.S. Navy 2015). Banger supports the Ohio class nuclear ballistic-missile submarines in their

intermediate-level maintenance (Riposo et al. 2008). The Everett site located at Naval Station Everett operates repair shops and refit piers (U.S. Navy 2015e). Everett was originally intended to be a homeport for U.S. Navy Battle Groups and currently houses and performs continuous maintenance for the USS Abraham Lincoln, CVN-72, and the surface ships supporting CVN-72. The San Diego detachment located at Naval Station San Diego operates small repair shops (U.S. Navy 2015e). PSNS usually supplies between 600–800 workers for six-month intervals to complete the non-nuclear maintenance and incremental availability activities onboard carriers stationed in San Diego (U.S. Navy 2015e). The final detachment located in Yokosuka, Japan detachment performs maintenance to support the only forward deployed U.S. nuclear carrier, USS George Washington, CVN- 73 (U.S. Navy 2015e). In 2006, PSNS executed approximately 1.8 million man days-worth of work. In 2008, NAVSEA 04 estimated at least 1.5 million man-days of annual work until 2013 (Riposo et al. 2008).

The current shipyard paradigm suggests the impact of an inefficient organization of shipyard work has a large economic impact. The sheer leverage of 3.8 million man-days times the average rate of pay for a laborer (assumed to nominally be \$325 per day, fully burdened) means the U.S. Navy spends \$1.3 billion on labor annually. By changing the organizational structure to a new approach instead of the current approach, work efficiencies should improve.

B. SHIPBUILDING INDUSTRY CONCERNS

Cost growth in the U.S. Navy shipbuilding construction and maintenance industry has been a long-standing problem. When the U.S. Navy awards a shipbuilding contract, the price in the contract is a compilation of many different areas and factors. The overall construction and maintenance cost of a ship can be decomposed into 4 main categories: labor, material, contractor overhead, and Navy-furnished equipment—all of which the Navy is required to pay (GAO 2005). Labor encompasses the hours worked for production, engineering, and direct worker support (GAO 2005). Labor costs include the fully-burdened hourly wages paid to the worker. Construction materials include the raw materials themselves- for example, steel, cooper, aluminum- any tools or miscellaneous

parts necessary to complete the work, and any necessary subcontracts (GAO 2005). Contractor's overhead encompasses all items associated with maintaining the workforce and the infrastructure of the company (GAO 2005). Worker's medical insurance, vacation time, retirement benefits, taxes, and facilities maintenance, and utilities all fall into contractor overhead (GAO 2005). Finally, the U.S. Navy furnished equipment includes any items procured by the U.S. Navy but provided to the contractor for ship installation. Specific electronics or weapon systems are considered Navy-furnished equipment (GAO 2005).

The GAO examined the cost increase in U.S. Navy shipbuilding in their 2005 report entitled, *Improved Management Practice Could Help Minimize Cost Growth in Navy Shipbuilding Programs*. This study analyzed eight ship building programs- DDG 91 and 92, CVN 76 and 77, LPD 17 and 18, and SSN 774 and 775. These programs exhibited a cost overrun of \$2.1 billion and have the potential to reach \$3.1 billion overrun unless shipyards remain vigilant to meeting their current schedules and maintaining their current efficiency. Of the \$2.1 billion in overruns, 57 percent is due to increase in labor hours, overhead rates, and labor rates (GAO 2005). The labor hour increase varied between 33 percent and 105 percent, costing the U.S. Navy an additional 34 million hours of extra labor (GAO 2005). This additional labor hour increase cost the U.S. Navy \$1.3 billion.

The labor hour growth due to cost overruns also increased the amount of overhead by \$457 million (GAO 2005). This overhead increase is only due to the fact that the same number of workers worked more hours. The overhead rate remained the same and the benefits the worker received such as vacation and sick days accrued and medical insurance remained constant. The amount of overhead increased due to the increased number of hours worked. Since overtime pay is typically greater than regular work hour pay, and overhead is attached to the worker's hourly rate as a multiplier, the amount of overhead recovered is higher for overtime work than it is for regular work. In other words, the contracted company benefits from overtime work, in the same way as the worker benefits. The U.S. Navy should also benefit if the availabilities are shorter.

The GAO reported shipbuilders attributed this cost increase to a lack of skilled, experienced workforce. Shipbuilders claim the tasks required to complete the availability were extremely complex and the shipyards simply did not have the workforce capable of completing these tasks. This inexperience led to a significant amount of rework being accomplished through an increase in worker overtime (GAO 2005). The shipbuilding companies, however, should manage their business differently so they are not faced with a shortage of unskilled workers. Introducing the “best value” approach into the shipyards will help shipbuilders manage this problem.

The GAO article highlights the public shipyards’ challenge in maintaining the depot-level competencies the fleet requires for efficient maintenance—a concern for the shipbuilding industry. As previously discussed in Chapter III, the inconsistency and ambiguity in depot-level maintenance workload stems from the ever changing size and compilation of the fleet, the uncertainty of maintenance requirements caused by new classes of ships and the unexpected operational requirements of the fleet (Riposo et al. 2008). However, at the process level, shipyard work is no different from any other manufacturing company. Complexity is not an issue for competent management, and uncertainty is not a problem for good management. Too much talk of the consequences and very little discussion of the causes is the recipe for a need to change in how to manage shipyards more efficiently.

C. PUBLIC SHIPYARDS AND THE CONTRACTING VEHICLES UTILIZED

In the U.S. Navy, there are a wide variety of contract types available to accommodate for the variability and large quantity of supplies and services purchased by each governmental agency. The different contract types vary by the amount of responsibility each party assumes for the costs of performance risk, when the risk is assumed, as well as the timing and amount of incentives offered to the contractor for achieving work at or above a specified standard. The contract types can be divided into two main categories: fixed-price and cost-reimbursement (Federal Acquisition Regulation 2005). In the shipbuilding industry, the type of contract selected can dramatically affect the final cost and quality of the ship (GAO 2013).

Firm-price contracts can be further broken down into four main categories: firm-fixed-price, fixed-price-with-economic-adjustment, fixed-price-incentive, and fixed-price-with-redetermination (GAO 2013). In the shipbuilding industry, firm-fixed-price and fixed-price-incentive (firm target) are the most common types of firm-price contracts utilized (GAO 2013). In a firm-fixed-price, the contractor assumes all of the performance costs and resulting profit or loss responsibility (Federal Acquisition Regulation 2005). Firm-fixed-price contracts can provide a direct incentive to the shipbuilder to produce a ship at the expected level of quality in a timely manner (GAO 2013). Fixed-price-incentive contracts are “a fixed-price contract that provides for adjusting profit and establishing the final contract price by a formula based on the relationship of final negotiated total cost to total target cost” (Federal Acquisition Regulation 2005, 16.4-3). Fixed-price-incentive contracts are commonly used for follow-on ship class contracts (GAO 2013).

Similar to the decomposition of firm-price contracts, cost-reimbursement contracts can be broken down into four main categories: cost-plus-award-fee, cost-plus-incentive-fee, cost-plus-fixed-fee, and cost and cost-sharing (GAO 2013). Cost-reimbursement contracts permit payment of the contractor’s incurred costs (Federal Acquisition Regulation 2005). In shipbuilding, the most common cost-reimbursement contract is with incentive fees and typically employed for a class’ lead ship (GAO 2013). More about shipbuilding contracts can be found in Appendix B.

V. SYSTEMS ENGINEERING, SYSTEMS, AND SYSTEMS OF SYSTEMS

Systems engineering (SE) is a logical approach to investigate and solve problems involving the design, assembly, and maintenance of varying scales of problems covering a wide variety of disciplines within a given set of constraints (Kugler 2014). SE begins by defining the problem at hand, determining the boundaries and scope of the problem, and identifying who is interested in the problem, the stakeholders, and proposing the eventual solution. Then, the problem or system is broken down further into subsystems and components. The problem decomposition allows for an in depth view into each individual element of the problem, thus providing insight into each interaction and function. Additionally, the decomposition allows the problem to be seen from multiple different angles, allowing a thorough analysis of the system to occur (Kugler 2014).

A. WHAT IS SYSTEMS ENGINEERING?

The International Council on Systems Engineering, INCOSE, is the internationally recognized body for systems engineering. The INCOSE states the generally accepted definition of SE as:

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem. Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. (INCOSE 2015)

The U.S. Department of Transportation Federal Highway Administration graphically represents the classic SE Vee diagram, a tool used to help Systems Engineers solve the problem at hand. The graphical version of the SE Vee diagram is shown in Figure 15. The Vee shows a top down design concluding at implementation followed by a bottom up approach for realization of the production.

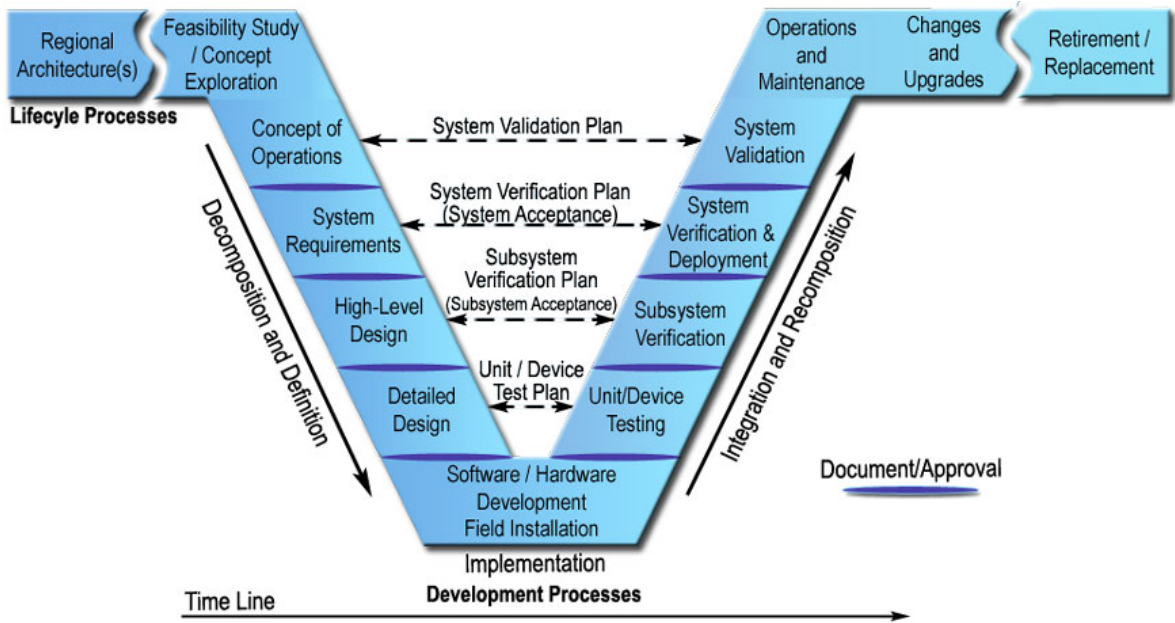


Figure 15. Prototypical Systems Engineering Vee Diagram (from U.S. Department of Transportation Federal Highway Administration 2015)

The top down design shown on the left hand branch of the Vee begins with the initial stakeholder analysis. The stakeholder analysis is accomplished through research, interviews, and a feasibility study. The compilation of this information leads to a concept of operations (CONOPS). The CONOPS is an extremely high-level view visually showing where and how the system will be used and the different types of interactions the system will encounter. The stakeholder analysis and the CONOPS reveal the requirements for the system. These requirements are then used to conduct an analysis of potential alternatives. If no viable alternatives already exist, the requirements are mapped back to system functions (U.S. Department of Transportation Federal Highway Administration 2015). The requirements are also the driving components for creating the high level and detailed design of the system. Each step in the top down design produces a set of products. These products become the inputs into the right hand, bottom up realization, branch of the Vee (DAU 2015).

The right hand branch sets forth a process to build, integrate, test, verify, and validate the system being built. The realization process starts begins on a small scale, combining individual components, and then graduates to combining those components

into subsystems and finally into a functioning system (U.S. Department of Transportation Federal Highway Administration 2015). Through the realization process, each outcome is constantly mapped back to the system level requirements ensuring the system was built correctly (verification) and the correct system was built to meet the needs and requirements of the customer (validation). The process itself is recursive, iterative, and constantly changing and updating (DAU 2015).

B. SYSTEMS

Systems engineering can be used to realize new solutions to existing problems providing increased functionality and improved systems. Systems are found in every aspect of life but are subject to certain physical, functional and behavioral boundaries. Systems can also be combined together to form systems of systems (SoS), causing the expansion of the individual system boundaries, increasing the overall systems functionality.

The differences between systems and SoS may seem trivial at first glance. Professor Gary Langford gave a lecture titled “Systems Engineering Integration: Lesson 1” from July 14–17 at the Naval Postgraduate School discussing systems and SoS. In his lecture, he discussed how both systems and SoS share qualities such as being metastable, internally agile and externally adaptable. They differ in their reciprocal ability. SoSs are built out of individual systems. Therefore, it is necessary to have a thorough understanding of systems before comprehending SoSs.

The term “system” can have multiple definitions; however, all definitions have related aspects. INCOSE defines a system as “an interacting combination of elements to accomplish a defined objective. These include hardware, software, firmware, people information, techniques, facilities, services, and other support elements.” The American Heritage Dictionary of the English Language defines a system as “a group of interacting, interrelated, or interdependent elements forming a complex whole.” Langford further defines a system in his 2014 lecture as “a set of objects and processes that are either dependent or independent but interacting pair-wise - temporarily or physically,” as graphically represented in Figure 16.

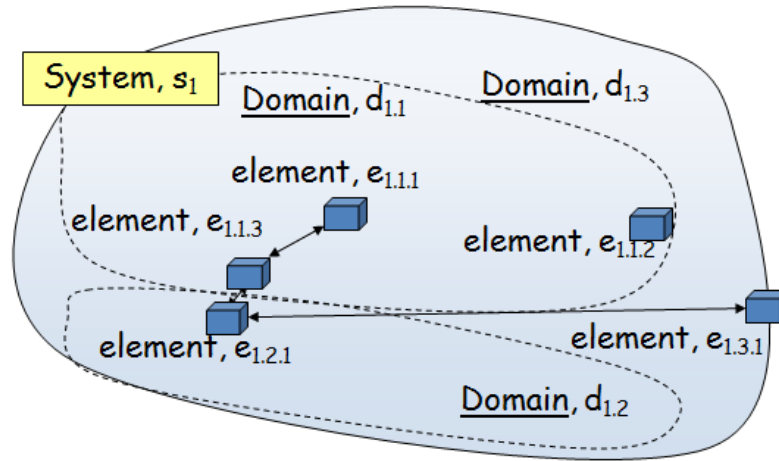


Figure 16. Graphical Representation of a System (from Langford 2014 lecture “Systems Engineering Integration: Lesson 1”)

From Langford’s definition, a system is a collection of interrelating elements that together form a larger whole in response to a set of derived requirements. Langford states that in order for a system to exist, it must be Metastable, Internally agile, Externally adaptive, and are formed by NON-reciprocal action (MIEN). All these definitions have a system comprised of multiple objects interacting through an exchange of EMMI (Kugler 2014, citing Langford 2012).

Additionally, a system has a distinct boundary surrounding the interaction of the objects. The boundary does not, however, require every object in the system to interact with every other object. Langford in his 2014 “Systems Engineering Integration: Lesson 1” states the boundaries experienced by the objects represent long-term and occasional interactions as well as emergent properties and characteristics found in both systems and system-of-systems. Additionally, the situation dictates that objects may or may not be independent of each other and may interact randomly or may have causal relationship with each other. Each object in the system services a distinct purpose to the system as a whole. Therefore, when one small object in a system changes, the entirety of the system changes (Kugler 2014).

(1) Physical Boundary

“The physical boundary is the actual tangible dimensions, construction, and any other physical limitations of the object, such as the walls and floors” (Kugler 2014, 41, citing Langford 2012). The services provided by shipyards are determined in part by the shipyard’s physical boundaries. Outside structures such as a fence, neighborhoods, or natural boundaries (bodies of water or mountains) can not only determine the physical boundary of the shipyard but can prevent the expansion of the shipyard (Kugler 2014). For example, the shipyard size will determine which capabilities such as dry docking and machine repair facilities it can support within its physical boundary. When operating at full capacity, the shipyard cannot increase its capability for one function without relinquishing the required space used by another function. In order to prevent a system from operating in unrealistic circumstances, the physical limitations of the system must be understood.

(2) Functional Boundary

“A functional boundary results from the use of an object as manipulated by another object via the connection between the two objects” (Kugler 2014, 41, citing Langford 2012). Connections occur when two objects interact. Functions permit the use of the objects and are carried out by the participation of the objects (Kugler 2014). When a shipyard worker is hired at a shipyard (the interaction of two objects), the functions “to work” and “to receive work” are performed. The function “to work” enables the shipyard worker the ability to provide services to the shipyard. Functions are relevant and important because they provide the measurable metric of performance, which can be used as a comparison across varying types of business.

(3) Behavioral Boundary

“A behavioral boundary arises from the existence (or non-existence) of functions or objects” (Kugler 2014, 42, citing Langford 2012). Functions elicit a human reaction whether or not they exist. For example, if the function ‘to work’ does not exist for a shipyard worker, he or she has options with regards to subsequent behavior. First, one can continue to apply for different jobs at the current shipyard hoping to find work. One

can hope that shipyard will expand in some way shape or form to create new jobs, or that person can also apply to other shipyards or businesses to find work.

C. WHAT IS A SYSTEM OF SYSTEMS?

When any fraction of multiple independent or dependent systems interacts together through the exchange of EMMI, systems of systems are formed allowing each individual system to achieve a greater benefit through the interactions with other systems than it would experience by operating independently. The time duration of these interactions may vary between SoSs. However, just like systems, the boundaries determine the type of interactions available to the SoS (Kugler 2014). Figure 17 graphically represents two systems interacting across their boundaries through the exchange of EMMI between a common element.

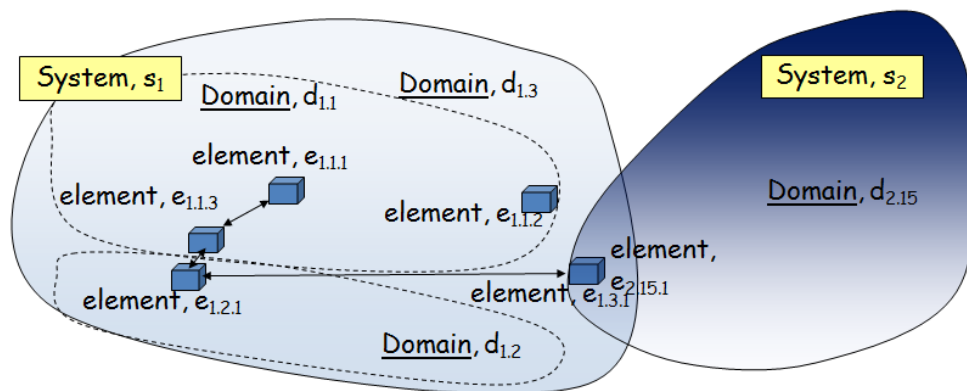


Figure 17. Graphical Representation of a SoS (from Langford 2014 lecture “Systems Engineering Integration: Lesson 1”)

D. HIGH-VALUE SYSTEMS-OF-SYSTEMS APPROACH

A high-value system-of-systems approach encourages both the company and management to utilize human capital management to empower employees to perform to their optimum level. The most difficult obstacle for management to overcome in a high value system is to relinquish control over the employees. By treating the employees as responsible adults, and not adolescents requiring constant supervision, direction, and control, companies may increase the human capital yield from each employee. When a

company hires an employee, it is buying the talent and dedication associated with that person, not simply a person who mindlessly sits in an office chair or works on a factory floor (Semler 2004). In his book *The Seven-Day Weekend*, Ricardo Semler sums up by stating, “Employees must be free to question, to analyze, to investigate; and a company must be flexible enough to listen to the answers” (17).

According to Christa Clapperton (2002), one way to empower the employee is through flexible working arrangements where workers dictate when to work, and where to work. Technology, such as computers, smart phones, secure company web pages and email, enables employees to work whenever and wherever they need, while sharing the knowledge and skills with coworkers (Clapperton 2002). Additionally, technology allows for e-learning to occur at the workplace or at home, depending on the employee’s and company’s preference. The flexible work arrangement places the employee in charge of their own career, and management should immediately realize productivity improvements (Clapperton 2002).

Another way to create a high value employee is to allow the employee to adjust his/her working hours. Adjusting working times not only allows the employee to compensate for traffic but each individual person’s biorhythms, which can increase their own personal level of productivity (Semler 2004). Employees should be encouraged to modify their work schedules to fit their personal needs and strike a balance between work, personal/family time, and free time. Allowing the employee to spread their 40-hour work week over the entire seven-day week leads employees to become more productive workers (Semler 2004). The increased productivity benefits the company as well as the individual because employees strike a balance between professional, personal and spiritual lives.

Employees do not work to create an inferior product, be unproductive, become bored, or be insubordinate. Employees want to work, especially when they realize that work is not the enemy of their personal freedom and self-interests (Semler 2004). Employees can pursue their own self-interests and the company interests with fewer conflicts. By allowing the employee to see that their self-interest is equal to company

interest, they are more dedicated to the job and work at hand, thus increasing their human capital to the company (Semler 2004).

Workplace stress exists in every job, but to create the ultimate high value employee, workplace stress should be kept to a minimum. Ricardo Semler in his book *The Seven-Day Weekend* states that “workplace stresses reflect the difference between expectation and reality” (46). The company should aim to minimize stress but recognize that a stress-free workplace is unrealistic. The most stress-free workplace exists when employees respect each other’s differences.

Another way to improve human capital management is to create a high value employee by utilizing integrated product teams (IPTs), also called self-directed work teams. IPT’s are self-led teams, which empower the worker to make decisions in determining how to tackle the problem at hand, and take ownership and pride in their work. Capozzoli, in his 2004 article *Succeed with Self-Directed Work Teams*, lays out six steps to ensure an IPT functions properly and gains the highest employee human capital return. First, the IPT must begin with a product vision and understand how the IPT fits into the organization at large. This vision allows the team members to understand where they fit and what roles they play in the larger organization. Secondly, management needs to provide the team with the necessary resources to complete the tasks at hand. Third, management is responsible for clearly stating the team’s expectations, but should not dictate how to accomplish the tasks. The IPT should remain free to determine their way forward promoting creativity and independence. Fourth, feedback loops should be in place between management and the IPT allowing for constant evaluation and communication. Fifth, management should inform the IPT of their operational boundaries, scope of control, and decision-making authority. This direction sets the parameters for the IPT to operate in, while allowing as much autonomy as possible. Finally, management takes on the role of a coach and mentor rather than a managerial boss formally dictating job responsibilities and descriptions. The creation of IPTs encourages the employee to become interested in and take ownership of the task at hand (Capozzoli 2004). If an employee lacks the necessary level of interest, management should help them move to another project to spur the interest (Semler 2004).

E. “BEST VALUE” SYSTEMS-OF-SYSTEMS APPROACH

The “best value” systems approach is concerned with finding the optimum combination of best performance for the lowest cost. The concept of value engineering was started by the General Electric Company in the 1940s (Miles 1961) and was first implemented in their 82 plants by 1952. In the 1960s, team-based reviews of products and production processes were implemented by Lucas and Dunlop, Philips Industries, Rolls Royce and other leading aerospace companies. At the First European Value Conference, M. Williams from Dunlop’s Group Management Services described “best value” as:

An organized approach to accomplish a function at the lowest cost. It is not another form of cost reduction programme. Cost reduction is cost orientated, and although costs may be reduced value and reliability are often reduced accordingly. Value analysis is function orientated and usually costs are reduced drastically while not affecting function; in fact, often increasing value and quality substantially. It can reduce costs considerably even after a Cost Reduction team has studied the same project. (Kashiwagi 2015, 1)

Williams highlights that value management and thus “best value” are not simply concerned with cost reduction. From Williams’ description, the fundamental principles of “best value” can be extracted as: reduced cost without compromising value and quality.

The “best value” systems approach in value management strives to find the best relationship between an object or program’s performance, expectations, and cost. The Office of Management and Budget (OMB) considers value analysis, value management, value control, and value engineering all synonymous (Kashiwagi 2015). In OMB Circular No. A-131 (Revised), issued on December 26, 2013, value engineering was mandated for all federal executive agencies—a practice actually put in place beginning in the 1960s. OMB described value engineering as:

A systematic process of reviewing and analyzing the requirements, functions and elements of systems, project, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life-cycle cost consistent with required levels of performance, reliability, quality, or safety. (OMB 2013, 3)

Value management strives to reduce cost, increase productivity, or improve quality and can be applied to “hardware and software; development, production, and manufacturing; specifications, standards, contract requirements, and other acquisition program documentation; facilities design and construction” (OMB 2013, 1). Successfully implementing value management can occur at any point in a system’s life cycle.

OMB further defines the term “best value” as “an item or process that consistently performs the required basic function at the lowest life-cycle cost while maintaining acceptable levels of performance and quality” (OMB 2013, 1). Additionally, the Inspector General performs value engineering audits to ensure the agencies are correctly reporting value engineering savings and to evaluate the robustness of the agencies value engineering policies, procedures and implementation (OMB 2013). OMB states that value engineering is “a well-established commercial practice for cutting waste and inefficiency that can help Federal agencies reduce program and acquisition costs, improve the quality and timeliness of performance, and take greater advantage of innovation to meet 21st century expectations and demands” (OMB 2013, 1).

In the “Enhancing Contract Performance Outcomes” panel from Proceedings of the Fourth Annual Acquisition Research Symposium Thursday Sessions Volume II held on May 17, 2007 at the Naval Postgraduate School, the concept of “best value” is described as:

The best-value environment focuses on securing the best-value vendor for the owner and on transferring all project risk to the outsourced expert. It considers the vendor’s past performance, ability to identify and minimize risk, preplanning foresight, and project knowledge. It requires the contractors to use their expertise to complete a project that fulfills the intent of the owner, and minimize controlled project risk at the beginning of the project. It forces accountability between all parties, and benefits vendors with foresight, experience, skill, and efficiency. It provides an environment that maximizes contractor profit, while minimizing owner resources. (447)

The results of “best value” have been validated by Arizona State University’s Dean Kashiwagi, the director of the Performance Based Studies Research Group (PBSRG). In Kashiwagi’s 13 years of research, 480 tests of “best value” were conducted

(Sullivan and Sullivan 2007). The two largest projects, \$100M City of Peoria Wastewater Treatment DB project in 2007 and the \$53M Olympic Village/University of Utah Housing project in 2001, found the contractor was able to be on time, on budget with no contractor-generated cost change orders and meeting the client's expectations 98% of the time (Sullivan and Sullivan 2007). Less than 1% of the time a surprise factor of nonperformance occurred (Sullivan and Sullivan 2007). Further Kashiwagi tests of the University of Hawaii in 2000 and University of Minnesota in 2006, "best value" was able to minimize the management effort of the client's constructor managers by 80 to 90 percent and by implementing "best value," the State of Hawaii was able to deliver 10 times the amount of projects between 1997 and 2001 (Sullivan and Sullivan 2007). Additionally, in 2005 Kashiwagi was awarded the Corenet Global Innovation of the Year Award for testing at Harvard University and in 2000 the Tech Pono Award for the testing at the State of Hawaii (Sullivan and Sullivan 2007).

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VI. EXAMINATION OF THE CURRENT SHIPYARD SYSTEM

The current relationship between the government, permanent workers, contractors, contingent workers, and the unions is extremely complex and detailed. However, the current architecture of the shipyard can be broken down into a combination of three interacting systems: the shipyard/permanent employee system, the shipyard/contingent worker system, and the union/contingent worker system. These three systems form the public shipyard's systems of systems.

A. SHIPYARDS AS A SYSTEM OF SYSTEMS

Systems are a combination of objects placed together to obtain a desired outcome and increase functionality. Every object in the system provides a specific need or function to allow the current system architecture to operate. The three interacting systems: the shipyard/permanent employee system, the shipyard/contingent worker system, and the union/contingent worker system all work together to form the public shipyard SoS. When the word shipyard is used by itself and not in combination with another word, it refers to all people working within the shipyard with the exception of government management. Shipyard includes permanent workers, prime contractors, and contingent workers. Figure 18 shows a high-level depiction of the public shipyard system of systems.

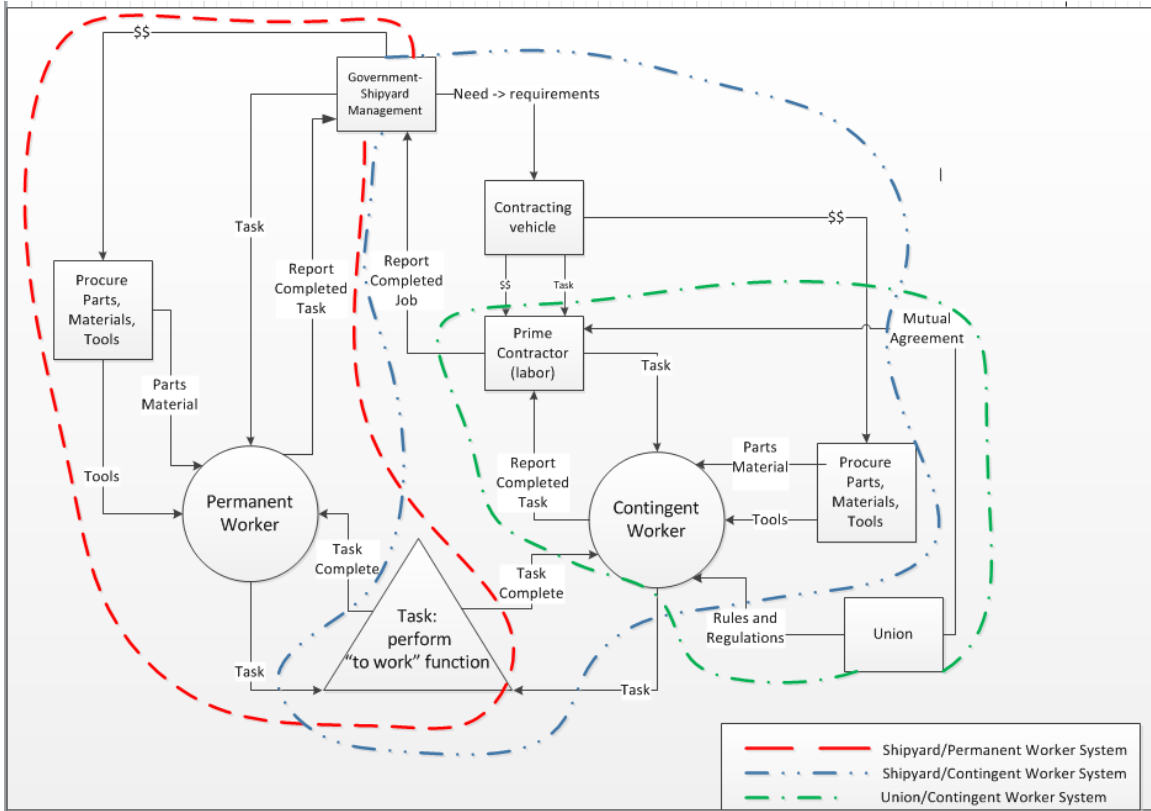


Figure 18. High-Level Conceptual Current SoS Architecture of a Public Shipyard

The interactions between the different systems in the public shipyard SoS provides benefits and increases the functionality of the whole system. The arrows in Figures 18 through 22 indicate the flow of information from the source (arrow tail) to the recipient (arrow head). The shipyard/permanent worker system interacts with the shipyard/contingent worker system through the tasks the permanent and contingent workers perform and through the overall guidance and structure provided by the shipyard for both systems. The government benefits from the systems interaction because the working relationship between the contingent worker and the permanent worker causes the tasks to be performed at a higher quality than if they were performed independently by the contingent and permanent workers. Additionally, the permanent and contingent workers both benefit from the collaboration experienced through the task completion.

The shipyard/contingent worker system and the union/contingent worker system interact through the prime contractor and the contingent worker. The contingent worker

benefits from this interaction through more standardized working conditions, wages, and benefits. The prime contractor also benefits by having a common expectation for each worker. Finally, the shipyard/permanent worker system has no interaction with the union/contingent worker system.

In the public shipyard/permanent worker system shown in Figure 19, the shipyard first provides the permanent worker with a task. Then, the shipyard is responsible for the funding of the procurement of parts, materials, and tools for the completion of the task. The permanent worker takes the task, and uses the parts, materials, and tools to perform the function “to work.” Once the task is complete, the permanent worker reports the completed task back to the shipyard and waits for further tasking.

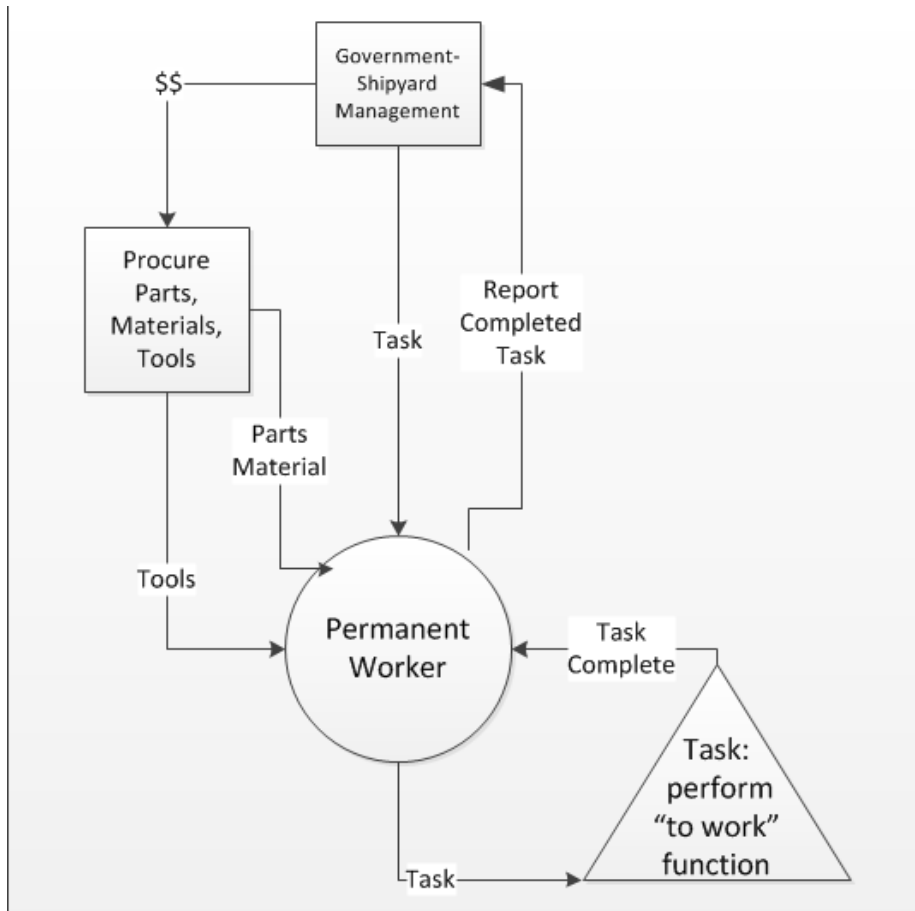


Figure 19. Current Public Shipyard/Permanent Worker Architecture

In the shipyard/contingent worker system shown in Figure 20, the government or shipyard first identifies a need. The shipyard then derives a set of requirements which must be fulfilled in order satisfy the given need. These requirements are then placed into a contract, bid, and awarded to a prime contractor to fulfill the labor aspect of the contract. The parts, materials, and tools are also purchased by the shipyard in order to satisfy the given need. The prime contractor employs a contingent worker to complete the given task. The contingent worker takes the task, parts, materials, and tools and performs the function “to work.” Once the contingent worker completes the task at hand, he or she delivers a product to the prime contractor who in turn delivers a final product to the shipyard.

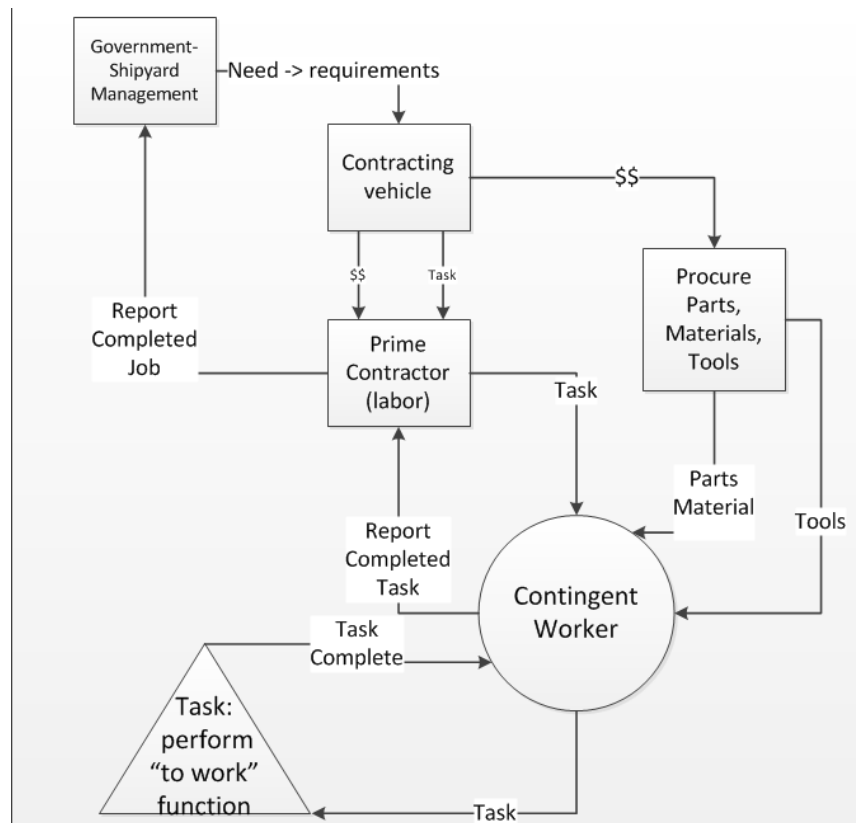


Figure 20. Current Shipyard/Contingent Worker Architecture

In the union/contingent worker system shown in Figure 21, the union interacts with the contingent worker through set rules and regulations. The union also has a mutual agreement with the prime contractor with regards to the contingent worker’s employment. The prime contractor still retains the responsibility to task the contingent worker and after completion of the task, the contingent worker reports back to the contractor.

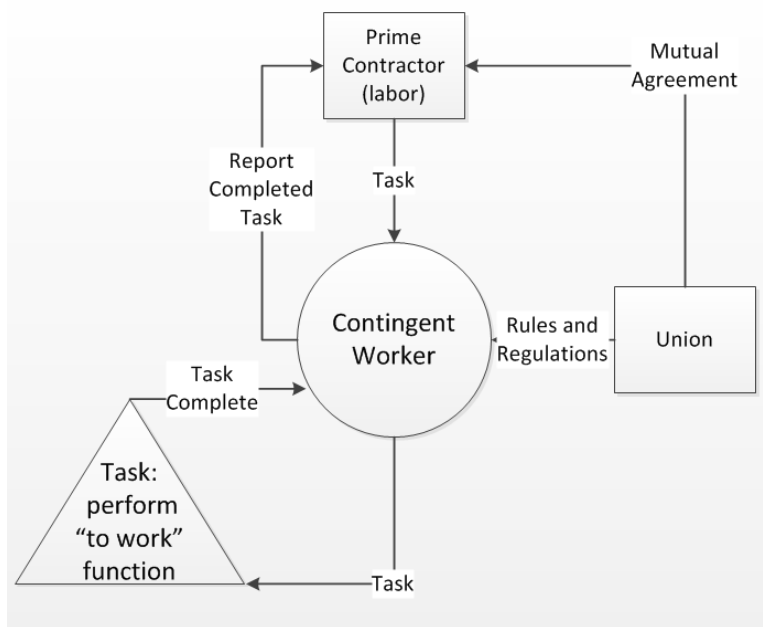


Figure 21. Current Union/Contingent Worker Architecture

In the current architecture, all the interactions and relationships within the system forming the collective public shipyard SoS are necessary and any elimination of an object or interaction would fundamentally change the SoS, causing a failure. Although all the interactions are necessary, they are not all performed at the optimum efficiency level. By slightly altering the shipyard SoS, a more effective and efficient system can emerge.

B. UNINTENDED CONSEQUENCES OF THE CURRENT SYSTEM

The problem faced by the public shipyards is delays in ships completing availabilities. In general, the ships are delivered behind schedule. Ships delivered behind schedule increases the total number of ships in the availability life cycle. The greater the

number of ships in the availability life cycle, the greater the number of ships the U.S. Navy must commission and maintain. The larger the number of ships, the greater the labor force required to operate and maintain the ships which increases the total cost to the U.S. Navy. Multiple factors are to blame for ships being delivered behind their scheduled availability. Contributing factors to the ship delays are the enterprise organization of the shipyards, and the contracting vehicle shipyards use to let shipyard contracts.

Data provided electronically by NAVSEA 04 in April 2015, summarized in Table 1, showed NNSY completed 10 Chief of Naval Operations, CNO, Submarine Availabilities from 2007–2014. Campbell in his 2006 article, “Using Incentives to Reduce Overtime Expenditures” from *Defense AT&L*, states that each additional day of work in a naval shipyard costs \$100,000. Using this \$100,000/day assessment, the cost impact on the U.S. Navy was determined as either the availability saving the U.S. Navy money (a positive value in the table) by the availability completing ahead of schedule, or costing the U.S. Navy money (a negative value in the table) due to the availability ending behind schedule.

		Number of Days Ahead (+) or Behind (-) Scheduled Availability End Date	Cost Impact on Navy: (+) savings or (-) additional funding required
NNSY CNO SUBMARINE AVAILABILITIES	SSN 750 NEWPORT NEWS (EOH)	-180	-\$18,000,000.00
	SSN 756 SCRANTON (DSRA)	-43	-\$4,300,000.00
	SSN 714 NORFOLK (DSRA)	-10	-\$1,000,000.00
	SSN 764 BOISE (DSRA)	1	\$100,000.00
	SSN 765 MONTPELIER (DSRA)	12	\$1,200,000.00
	SSN 710 AUGUSTA (IA)	1	\$100,000.00
	SSN 690 PHILADELPHIA (IA)	1	\$100,000.00
	SSBN 732 ALASKA (ERO)	-16	-\$1,600,000.00
	SSBN 734 TENNESSEE (ERO)	-101	-\$10,100,000.00
	SSBN 736 WEST VIRGINIA (ERO)	-156	-\$15,600,000.00

Table 1. NNSY CNO Submarine Availabilities 2007–2014

From Table 1, the Engineering Overhaul (EOH) availability came in behind schedule by 180 days. Half of the four dry docking selected restricted availabilities (DSRA) were delivered behind schedule: 43 days for SSN 756 and 10 days for SSN 741. SSN 764 and SSN 765’s DSRA’s came in ahead of schedule by one and 12 days, respectively. Schedule data was unavailable for the two inactivation availabilities. Finally, all three engineering refueling overhauls (ERO) were behind schedule by 16,101, and 156 days for SSBN 732, SSBN 734, and SSBN 736. On average, NNSY CNO submarine availabilities cost the U.S. Navy an additional \$4.9 million each by not completing the availabilities on time.

The data provided electronically by NAVSEA 04 in April 2015 showed the submarine CNO availabilities at Portsmouth Naval Shipyard experienced similar results and is summarized in Table 2.

		Number of Days Ahead (+) or Behind (-) Scheduled Availability End Date	Cost Impact on Navy: (+) savings or (-) additional funding required
Portsmouth Naval Shipyard CNO Availabilities 2007-2014	SSN724 (EOH)	-161	-\$16,100,000.00
	SSN 723 (EOH)	-157	-\$15,700,000.00
	SSN 725 (EOH)	-47	-\$4,700,000.00
	SSN 751 (EOH)	3	\$300,000.00
	SSN 752 (EOH)	-137	-\$13,700,000.00
	SSN 691 (PIRA)	-68	-\$6,800,000.00
	SSN 700 (PIRA)	-116	-\$11,600,000.00
	SSN 711 (PIRA)	0	\$0.00
	SSN 720 (PIRA)	-11	-\$1,100,000.00
	SSN 706 (PIRA)	-17	-\$1,700,000.00
	SSN 709 (INACT)	-19	-\$1,900,000.00
	SSN 691 (INACT)	29	\$2,900,000.00
	SSN 774 (EDSRA)	-140	-\$14,000,000.00

Table 2. Portsmouth Naval Shipyard CNO Availabilities 2007–2014

From 2007–2014, 13 CNO availabilities were completed in Portsmouth, San Diego and New London facilities. 10 were delivered late by between 11–161 days. One boat, SSN 711, was delivered on time from the pre-inactivation restricted availability

(PIRA) and only two boats were delivered ahead of schedule. SSN 751 was delivered three days ahead of schedule from her EOH availability and SSN 691 was delivered 29 days ahead of schedule from her inactivation availability. On average, Portsmouth Naval Shipyard CNO submarine availabilities cost the U.S. Navy an additional \$6.5 million each by not completing the availabilities on time.

The carrier data provided electronically by NAVSEA 04 in April 2015 showed better results than the submarine CNO availabilities at Norfolk and Portsmouth summarized in Table 3.

		Number of Days Ahead (+) or Behind (-) Scheduled Availability End Date	Cost Impact on Navy: (+) savings or (-) additional funding required
NNSY CNO CARRIER AVAILABILITIES (PIA)	USS GEORGE WASHINGTON	3	\$300,000.00
	USS THEODORE ROOSEVELT	1	\$100,000.00
	USS DWIGHT D. EISENHOWER	-1	-\$100,000.00
	USS HARRY S. TRUMAN	4	\$400,000.00
	USS RONALD REAGAN	-1	-\$100,000.00
	USS DWIGHT D. EISENHOWER	-58	-\$5,800,000.00
	USS GEORGE H. W. BUSH	-11	-\$1,100,000.00

Table 3. NNSY CNO Carrier Availabilities 2007–2014

Eight CNO availabilities, seven planned incremental availabilities (PIA), and one docking planned incremental availabilities (DPIA) were completed between 2006 and 2012. Of the seven PIAs, three were delivered on time, two were delivered within one day of the scheduled delivery, and the final two were delivered 58 and 11 days late. The DPIA for USS Harry S. Truman, however, was delivered 107 days late. On average, NNSY CNO carrier availabilities cost the U.S. Navy an additional \$900,000 each by not completing the availabilities on time.

The data shows the vast majority of the ships are delayed in their availabilities. The consequences of the delayed ships are missions are under staffed; more ships are needed because fewer ships are available; ships cost more to be repaired because the availabilities are longer; workers are accustomed to a certain cadence of work and effort

which satisfies their expectations; and management is focused on meeting the expectations of the worker- not the expectations of the U.S. Navy. The problem is the system of acquisition, contracting, and managing the old systems can be updated to reflect a systems “best value” view of shipyard work. The solution to the problem is to change the expectation of the workers and management. By using the current availability data shown in Tables 1–3 and conducting a what-if analysis to compare the current, old system to the proposed, new “best value” system founded by Arizona State University’s Dean Kashiwagi, the director of the Performance Based Studies Research Group, the overall labor and cost savings of using “best value” theory can be shown to be both beneficial and effective to the U.S. Navy.

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VII. A NEW APPROACH TO SHIPYARDS: HIGH-VALUE-BEST-VALUE SYSTEM OF SYSTEMS

In order for public shipyards to achieve the best product from the contractors, a new High-Value-Best-Value system-of-systems (HVBV SoS) approach should be implemented. Shipyards should use the practice of “best value” rather than “best price” as the leading agent in selecting a prime and subcontractor. By using “best value,” different leverage will be needed by the government. Performance information and reputation motivate the contractors and raise their level of pride and workmanship, which benefits the shipyard with quality products at affordable prices. Additionally, valuing the employees as high-value assets will increase employee productivity and morale. The result is an overall increase in the value of human capital that the workers experience in the shipyard. Although the transition into a HVBV SoS may prove difficult at first for both the shipyards and the contractors, the overall mutual benefits will far outweigh the current shipyard-contractor structure.

A. SHIPYARDS AS HIGH-VALUE-BEST-VALUE SYSTEMS OF SYSTEMS

The new HVBV SoS take the same general SoS structure of the shipyards shown in Figure 18 and proposes two major changes. First, the contracting vehicle the shipyards use for fulfillment of the needs and requirements changes drastically from price driven selection to a “best value” selection. Secondly, instead of the permanent worker and the contingent worker working in parallel on the same task, the workers join together to form an integrated project team (IPT). The IPT then jointly performs the task “to work.” The high level, macro view of the shipyard’s HVBV SoS is shown in Figure 22.

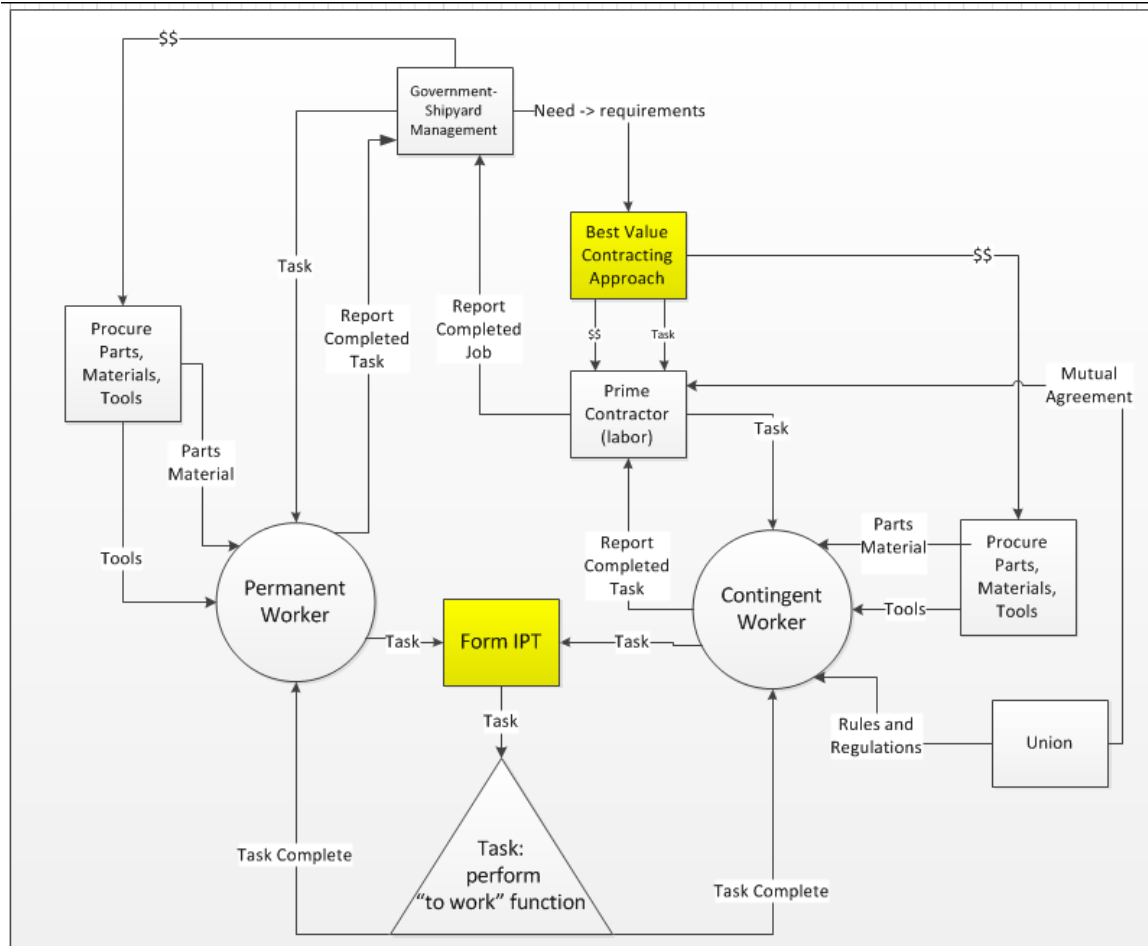


Figure 22. Proposed Shipyard HVBV SoS Architecture

1. Proposed “Best Value” System of Systems

The first major change, the “best value” contracting approach, would be utilized at the contracting level for the shipyards as an alternative means of contractor selection. By looking at past performance, the shipyards can forecast the performance of the contractor on future projects. According to Dean Kashiwagi (2015), eight key areas for the shipyards to focus on when selecting a “best value” contractor are:

1. Ability to manage the project cost (minimize change orders)
2. Ability to maintain project schedule (complete on time or early)
3. Quality of workmanship

4. Professionalism and ability to manage (including responses and prompt payment to suppliers and subcontractors)
5. Close out process (no punch list upon turnover, warranties, as-built, operating manuals, tax clearance, and submitted properly)
6. Communication explanation of risk and documentation (construction interface completed on time)
7. Ability to follow the user's rules, regulations, and requirements (housekeeping, safety)
8. Overall customer satisfaction and hiring again based on performance (comfort level in hiring contractor again)

Contractors that are able to perform well in all eight areas will minimize the overall risk to the shipyards and themselves.

The “best value” approach to contracting would begin immediately with close shipyard-contractor interaction. The “best value” process is broken down into three primary phases: selection, preplanning/quality control, and risk mitigation (Sullivan and Sullivan 2007). The composition of “best value” is shown in Figure 23.

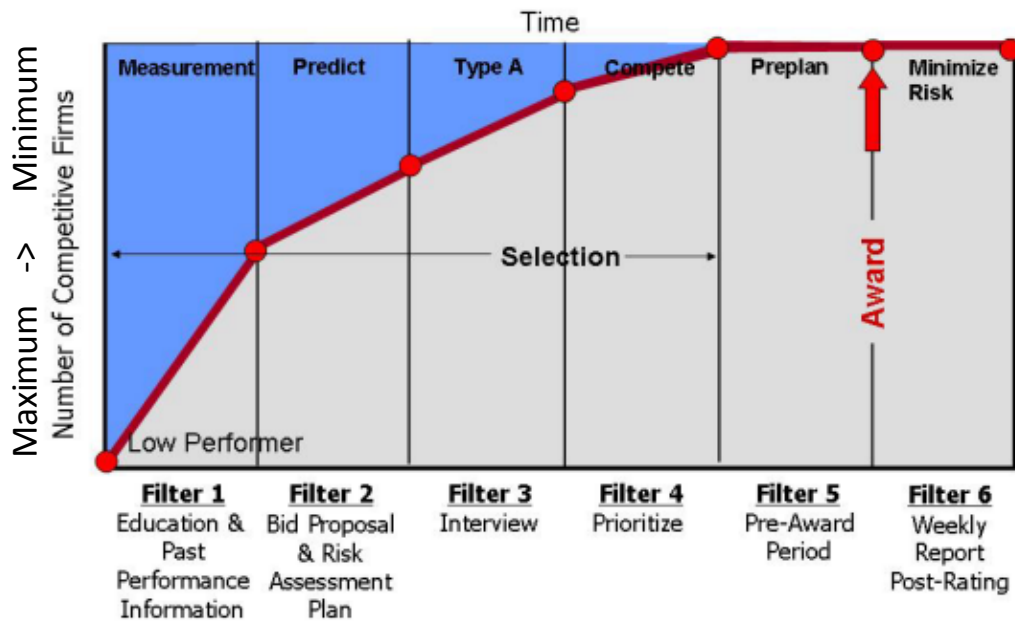


Figure 23. “Best Value” Natural Selection (from Sullivan and Sullivan 2007)

The selection of a “best value” contractor begins by soliciting contractor proposals and selecting them in a blind selection. The blind selection removes any potential governmental bias towards the contractor. During the pre-award phase of the contract, the finalized detailed project plan and all the preplanning for the work tasks are completed by the contractor for government review. The finalized detail project plan is the justification for the contractor’s proposal. The contractor selection then is based on the best past performance, the ability to minimize risk, and the best history for the lowest competitive cost, not simply lowest cost as previously used. The shipyards select the contractor with the highest performance at the given price.

After the contract is awarded, the contract details risks by more thoroughly identifying and detailing risks and then by developing a risk management plan. The specification and requirements detailed in the contract are only the intent of the shipyard, not an error-free detailed plan of the final project. Contractors should brief the government on how they intend to deliver the work tasks. Additionally, all uncontrolled risks are to be minimized by the contractor. The project schedule is developed to help aid in risk mitigation. Weekly risk reports from the contractor are required by the government identifying all schedule uncertainties, performance issues, and any other critical shipyard dictated items. These weekly risk reports force the contractor to think and plan continually for future problems. Ideally, the risk mitigation program should be simple in structure, systematic in process, and have direct accountability for the intention of the work effort.

By conducting risk mitigation techniques and selecting the contractor based on best value, the risk shifts from the government to the contractor who is the expert in the contracted field. It is more important for the contractor to be competent in the contracted field than the shipyard’s technical representative. By employing this technique, there is minimal management oversight required by all parties. The shipyard could avoid cost and schedule risks and overruns later in the program’s life cycle. By requiring the contractor to assume the program risk, the contractors must quickly self-identify risks, and measure and track risks—forcing active and continuous risk mitigation techniques to be

implemented. The shipyard assumes contractors will control all risks under their influence and minimize the risks they do not control.

Because the contractor is now responsible for risk mitigation, the government should see a decrease in change orders and an elimination of budget and estimation errors. Additionally, by utilizing best value, the cash flow risks are minimized. By self-identifying risks, the contractor should place every item on the project's critical task list forcing the planning of each item. If the contractor plans this way, schedules the discovery of an item, and is able to appropriately estimate when they expect to discover something missing through an examination of similar availabilities and previous work experiences, the contractor will provide a budgetary margin to appropriately accommodate for problems that may arise.

One key to "best value" is collaboration between the contractor and the shipbuilder early through constant dialogue. Shipyards should not dictate exactly how the contractor should perform the work tasks, because in general, the shipyards have a lower expertise level and are not as qualified as the contractor. The lack of shipyard worker experience compared to contingent worker experience causes the shipyard to end up assuming risk. Instead, let the contractors lead the dialogue in their areas of expertise. Shipyards need to evaluate the contractor based on nontechnical information. The nontechnical information provides the shipyards the basis for selecting the best-valued contractor to perform the work. In order for the shipyard to evaluate the non-technical information, constant communication between all parties must occur.

2. Quantitative Comparison of "Best Value" with Existing System of Operations

To show quantitatively the impact of introducing the best value portion of the HVBV SoS, the availability data provided electronically by NAVSEA 04 in April 2015 was re-evaluated under the current shipyard architecture and then under "best value" criteria. The first assumption made was there are three main reasons for an availability delay: a parts issue, a labor issue, or an unexpected change issue. A parts issue caused an availability delay in one of three ways: the part did not arrive at the shipyard, the part

arrived at the shipyard but was the incorrect part, or the part arrived at the shipyard but was subsequently lost. These issues are independent of each other. A labor issue caused an availability delay in one of two ways: the workforce possessed an inadequate skill set to complete the task at hand or there were an insufficient number of people to complete the task at hand. These issues are independent of each other. Finally, an unexpected change caused an availability delay in one of three ways: something on the ship broke during the availability, the workers discovered something unexpected on the ship that required fixing that was not originally planned or scheduled for repair, or the stakeholder desired something new to be installed, upgraded, or added onto the ship during the availability- also known as requirements creep. These issues are independent of each other. Any combination of a parts issue, labor issue, or an unexpected change issue is assumed to cause a delay in ship availability.

Risk is the expectation of losing something of value (i.e., significant loss, or the consequence) multiplied by the likelihood that a mechanism will result in the loss coming to pass (i.e., likelihood of loss). The traditional formulation of risk is modified by including the functional performance associated with mechanisms that are causal in changing risk (Langford 2012).

The first model created, depicted in Table 4 shows the risk percentage for each of the three main reasons for an availability delay: a parts issue, labor issue, or an unexpected change issue. The likelihood and consequence probabilities of the events were based on discussions with faculty advisors with inputs from subject matter experts on what mechanisms were causal. The implications of the causal effects from these mechanisms was then partitioned into three categories: for parts—“Does not arrive,” “Arrives but incorrect part,” and “Arrived and lost”; for labor, “Inadequate skills” and “Insufficient number of people”; and for unexpected changes, “Break something,” “Discover something unexpected,” and “Desire something new (requirements creep).” This new formulation of risk implies risk is a combination of parts, labor, and unexpected changes. For example, the likelihood of the part not arriving at the shipyard is 5% but the overall consequence for having the part available is 1% giving an overall risk percentage of 0.05%, i.e., 5% of 1% or $0.05 \times 0.01 = 0.0005 = 0.05\%$.

Assumptions for Current Shipyard Model (likelihood consequence= risk percentage)			
Percentage of time a parts issue is experienced	Does not arrive: 5% 1% = 0.05%	Arrives but incorrect part: 5% 1% = 0.05%	Arrived and lost: 5% 1% = 0.05%
Percentage of time a labor issue is experienced	Inadequate skills: 20% 2% = 0.4%	Insufficient number of people: 5% 5% = 0.25%	
Percentage of time an unexpected change occurs	Break something: 2% 2% = 0.04%	Discover something unexpected : 40% 50% = 20%	Desire something new (requirements creep): 5% 10% = 0.5%

Table 4. Assumptions for Current Shipyard Model

An average of the risk percentages for the current shipyard model was calculated to be 2.7% meaning the shipyard has a 2.7% chance of exceeding the scheduled time allotted for the availability. Then all the possible combinations of availability delays and the associated risk percentage were calculated and shown in Table 5.

Possible Combinations of Current Shipyard Model (parts issue/labor issue/unexpected change issue)		
Does not arrive/ Inadequate skills/ Break something: 0.49%	Arrives but incorrect part/ Inadequate skills/ Break something: 0.49%	Arrived and lost/ Inadequate skills/ Break something: 0.49%
Does not arrive/ Inadequate skills/ Discover something unexpected: 20.45%	Arrives but incorrect part/ Inadequate skills/ Discover something unexpected: 20.45%	Arrived and lost/ Inadequate skills/ Discover something unexpected : 20.45%
Does not arrive/ Inadequate skills/ Desire something new: 0.95%	Arrives but incorrect part/ Inadequate skills/ Desire something new: 0.95%	Arrived and lost/ Inadequate skills/ Desire something new: 0.95%
Does not arrive/ Insufficient number of people/ Break something: 0.34%	Arrives but incorrect part/ Insufficient number of people/ Break something: 0.34%	Arrived and lost/ Insufficient number of people/ Break something: 0.34%
Does not arrive/ Insufficient number of people/ Discover something unexpected: 20.30%	Arrives but incorrect part/ Insufficient number of people/ Discover something unexpected: 20.30%	Arrived and lost/ Insufficient number of people/ Discover something unexpected: 20.30%
Does not arrive/ Insufficient number of people/ Desire something new: 0.80%	Arrives but incorrect part/ Insufficient number of people/ Desire something new: 0.80%	Arrived and lost/ Insufficient number of people/ Desire something new: 0.80%
Does not arrive/ No labor issue/ Break something: 0.09%	Arrives but incorrect part/ No labor issue/ Break something: 0.09%	Arrived and lost/ No labor issue/ Break something: 0.09%
Does not arrive/ No labor issue/ Discover something unexpected: 20.05%	Arrived but incorrect/ No labor issue/ Discover something unexpected: 20.05%	Arrived and lost/ No labor issue/ Discover something unexpected: 20.05%
Does not arrive/ No labor issue/ Desire something new: 0.55%	Arrives but incorrect part/ No labor issue/ Desire something new : 0.55%	Arrived and lost/ No labor issue/ Desire something new: 0.55%

Table 5. Possible Combinations of Current Shipyard Model

The average of all possible combinations of the current shipyard model was calculated to be 7.11%.

Next, the same three main reasons for an availability delay: a parts issue, labor issue, or an unexpected change issue, were examined under the new “best value” criteria and risk percentages for each category were assigned and shown in Table 6. The likelihood and consequences percentages were based on the case study data from Arizona State University’s Dean Kashiwagi’s Performance Based Studies Research Group. For example, under the “best value” architecture, the likelihood of the part not arriving drops from 5% to 1% because the contractor is incentivized to diligently monitor the locations of all parts. The consequence of the part not arriving does not change with “best value” resulting in the risk percentage of 0.01%.

Assumptions for New "Best Value" Shipyard Model (likelihood consequence= risk percentage)			
Percentage of time a parts issue is experienced	Does not arrive: 1% 1% = 0.01%	Arrives but incorrect part: 1% 1% = 0.01%	Arrived and lost: 1% 100%= 1.00%
Percentage of time a labor issue is experienced	Inadequate skills: 1% 2% = 0.02%	Insufficient number of people: 1% 5% = 0.05%	
Percentage of time an unexpected change occurs	Break something: 2% 2% = 0.04%	Discover something unexpected: 1% 7% = 0.07%	Desire something new (requirements creep): 5% 10% = 0.5%

Table 6. Assumptions for New “Best Value” Shipyard Model

An average of the risk percentages for the new “best value” shipyard model was calculated to be 0.21%. Then, all the possible combinations of availability delays and the associated risk percentage were calculated and shown in Table 7.

Possible Combinations of New "Best Value" Shipyard Model (parts issue/labor issue/unexpected change issue)		
Does not arrive/ Inadequate skills/ Break something: 0.07%	Arrives but incorrect part/ Inadequate skills/ Break something: 0.07%	Arrived and lost/ Inadequate skills/ Break something: 1.06%
Does not arrive/ Inadequate skills/ Discover something unexpected: 0.10%	Arrives but incorrect part/ Inadequate skills/ Discover something unexpected: 0.10%	Arrived and lost/ Inadequate skills/ Discover something unexpected: 1.09%
Does not arrive/ Inadequate skills/ Desire something new: 0.53%	Arrives but incorrect/ Inadequate skills/ Desire something new: 0.53%	Arrived and lost/ Inadequate skills/ Desire something new: 1.52%
Does not arrive/ Insufficient number of people/ Break something: 0.10%	Arrives but incorrect part/ Insufficient number of people/ Break something: 0.10%	Arrived and lost/ Insufficient number of people/ Break something: 1.09%
Does not arrive/ Insufficient number of people/ Discover something unexpected: 0.13%	Arrives but incorrect part/ Insufficient number of people/ Discover something unexpected: 0.13%	Arrived and lost/ Insufficient number of people/ Discover something unexpected: 1.12%
Does not arrive/ Insufficient number of people/ Desire something new: 0.56%	Arrives but incorrect part/ Insufficient number of people/ Desire something new: 0.56%	Arrived and lost/ Insufficient number of people/ Desire something new: 1.55%
Does not arrive/ No labor issue/ Break something: 0.05%	Arrives but incorrect part/ No labor issue/ Break something : 0.05%	Arrived and lost/ No labor issue/ Break something: 1.04%
Does not arrive/ No labor issue/ Discover something unexpected : 0.08%	Arrived but incorrect/ No labor issue/ Discover something unexpected: 0.08%	Arrived and lost/ No labor issue/ Discover something unexpected: 1.07%
Does not arrive/ No labor issue/ Desire something new: 0.51%	Arrives but incorrect/ No labor issue/ Desire something new : 0.51%	Arrived and lost/ No labor issue/ Desire something new: 1.50%

Table 7. Possible Combinations of New “Best Value” Shipyard Model

The average of all possible combinations of the new “best value” shipyard model was calculated to be 0.57%.

The improvement in utilization from using the “best value” system in the shipyards can then be calculated by subtracting the average of all possible combinations of the new “best value” shipyard model from the average of all possible combinations of the current shipyard model and then dividing that value by the average of all possible combinations of the new “best value” shipyard model. The improvement in utilization using the average of all possible combinations is 11.55% meaning if the “best value” framework is utilized, the shipyard should realize a reduction in scheduled availability days by 11.55%. According the Dr. Dean Kashiwagi of Arizona State University, a change in organizational structure to “best value” vice the old current architecture should improve work efficiency by at least 15%. The calculated value of 11.55% is statistically the same as the 15% observed by Dr. Kashiwagi’s case studies of “best value” improvement in work efficiency. The shipyard model posed in Tables 5, 6, and 7 is consistent with the results of the “best value” case studies.

The improvement in work efficiency obtained from the model of “best value” in the shipyard (i.e., the utilization factor) was then applied to the availability data provided electronically by NAVSEA 04 in April 2015. Table 8 shows the current shipyard performance and the expected shipyard performance if the “best value” practices are implemented. For example, SSN 724’s EOH was scheduled to be complete in 673 days. However, the EOH actually took 834 days to complete causing SSN 724 to be delivered 161 days behind schedule or increasing the length of the availability by 24%. If the shipyard would implement the “best value” architecture, the number of scheduled days would decrease by 78 causing the revised planned availability to last 595 days. Campbell in his 2006 article “Using Incentives to Reduce Overtime Expenditures” from *Defense AT&L* states that each additional day of work in a naval shipyard costs \$100,000. Using this assessment, implementing the “best value” architecture would save the U.S. Navy \$7,775,129 for SSN 724’s EOH.

		Current Shipyard Performance					Shipyard Implementing "Best Value" Practices		
		Total Days Scheduled for Availability	Number of Days Ahead (+) or Behind (-) Scheduled Availability End Date	% of Scheduled Days behind (-) or ahead (+) of Scheduled Availability End Date	Total Number of Man-Days Required to Complete Availability	Actual Days Required to Complete the Availability	Number of Scheduled Days Saved with Best Value Improvement in Utilization	Number of Days the Availability Should be Scheduled for Accounting for Improvement in Utilization	Cost Savings to the Navy
Plymouth Naval Shipyard CNO Availabilities 2007-2014	SSN724 (EOH)	673	-161	-24%	299,909	834	78	595	\$ 7,775,129.41
	SSN 723 (EOH)	784	-157	-20%	308,041	941	91	693	\$ 9,057,505.88
	SSN 725 (EOH)	609	-47	-8%	293,459	656	70	539	\$ 7,035,741.18
	SSN 751 (EOH)	623	3	0%	302,513	626	72	551	\$ 7,197,482.35
	SSN 752 (EOH)	685	-137	-20%	339,506	822	79	606	\$ 7,913,764.71
	SSN 691 (PIRA)	282	-68	-24%	106,047	350	33	249	\$ 3,257,929.41
	SSN 700 (PIRA)	461	-116	-25%	174,655	577	53	408	\$ 5,325,905.88
	SSN 711 (PIRA)	170	0	0%	56,483	170	20	150	\$ 1,964,000.00
	SSN 720 (PIRA)	331	-11	-3%	102,304	342	38	293	\$ 3,824,023.53
	SSN 706 (PIRA)	191	-17	-9%	67,081	208	22	169	\$ 2,206,611.76
	SSN 709 (INACT)	385	-19	-5%	58,568	404	44	341	\$ 4,447,882.35
	SSN 691 (INACT)	336	29	9%	99,933	365	39	297	\$ 3,881,788.24
SSN 774 (EDSRA)	582	-140	-24%	264,503	722	67	515	\$ 6,723,811.76	
NNSY CNO CARRIER AVAILABILITIES (PIA)	USS GEORGE WASHINGTON	333	3	1%	237,962	336	38	295	\$ 3,847,129.41
	USS THEODORE ROOSEVELT	273	1	0%	213,339	274	32	241	\$ 3,153,952.94
	USS DWIGHT D. EISENHOWER	183	-1	-1%	183,807	184	21	162	\$ 2,114,188.24
	USS HARRY S. TRUMAN	181	4	2%	159,850	185	21	160	\$ 2,091,082.35
	USS RONALD REAGAN	182	-1	-1%	133,218	183	21	161	\$ 2,102,635.29
	USS DWIGHT D. EISENHOWER	240	-58	-24%	252,679	298	28	212	\$ 2,772,705.88
USS GEORGE H. W. BUSH	133	-11	-8%	132,948	144	15	118	\$ 1,536,541.18	
NNSY CNO SUBMARINE AVAILABILITIES	SSN 750 NEWPORT NEWS (EOH)	876	-180	-21%	342,761	1056	101	775	\$10,120,376.47
	SSN 756 SCRANTON (DSRA)	163	-43	-26%	44,402	206	19	144	\$ 1,883,129.41
	SSN 714 NORFOLK (DSRA)	160	-10	-6%	48,452	170	18	142	\$ 1,848,470.59
	SSN 764 BOISE (DSRA)	152	1	1%	71,865	153	18	134	\$ 1,756,047.06
	SSN 765 MONTPELIER (DSRA)	173	12	7%	61,896	185	20	153	\$ 1,998,658.82
	SSN 710 AUGUSTA (IA)	364	1	0%	71,197	365	42	322	\$ 4,205,270.59
	SSN 690 PHILADELPHIA (IA)	671	1	0%	111,866	672	78	593	\$ 7,752,023.53
	SSBN 732 ALASKA (ERO)	856	-16	-2%	426,487	872	99	757	\$ 9,889,317.65
	SSBN 734 TENNESSEE (ERO)	921	-101	-11%	455,487	1022	106	815	\$10,640,258.82
	SSBN 736 WEST VIRGINIA (ERO)	979	-156	-16%	541,316	1135	113	866	\$11,310,329.41

Table 8. "Best Value" Improvement in Utilization

By utilizing a “best value” architecture, the U.S. Navy would realize an average savings of \$4.98 million per availability based on the model shown and the availability data provided electronically by NAVSEA 04 in April 2015 instead of costing the U.S. Navy an additional \$4.65 million in the current shipyard availability architecture.

3. Proposed High-Value System-of-Systems Architecture

To change to a shipyard high value human capital management system of systems, the permanent worker and the contingent worker join together to form an integrated product team (IPT) instead of working in parallel on the same task. Stem, Boito and Younossi in their 2006 paper “System Engineering and Program Management: Trends and Costs for Aircraft and Guided Weapon Programs” define IPTs as “multidiscipline teams with the authority and accountability to produce a specific product within a program” (21). By creating an IPT, also known as a self-directed work team, the permanent worker and the contingent worker will feel empowered to take ownership of the task at hand. The formation of IPTs will allow the workforce to feel deeply involved in their work. The feeling of empowerment and involvement will lead to more unified workforce, with all working towards and feeling that their personal actions benefit the common goal. By utilizing IPTs, the shipyard can take greater advantage the internal knowledge of the workforce. The unspoken, implicit knowledge of each individual worker will now become open information for IPT team members to learn from and improve upon, resulting in a more educated workforce. The formation of IPTs will create more efficient employees resulting in fewer wasted project days thus saving the U.S. Navy time and money.

Managerial support is necessary for employees to realize the benefits of an IPT and to increase human capital in a shipyard. When shipyard leadership shows support of the IPT by accommodating flexible work schedules, empowering workers to respect their personal time, and encouraging behaviors that engender trust, reliability, and duty to the work, employees will work more diligently for the shipyard. Employees setting their work days and work hours are possible in a shipyard despite the manufacturing environment. Employees will not want to jeopardize their jobs by not satisfactorily

completing the work on time. The IPT team members will be cognizant enough to realize if they need to coordinate with outside groups to complete their given tasks. If employees fail to complete the required tasks, they are not the right employees for the shipyard and the shipyard should fire the employee. IPT employees will simply create their own hours according to what works for each individual team thus improving each individual team's effectiveness.

In order for a high performing IPT to be successfully, skilled leaders and team members are necessary as well as an organization that promotes openness and trust among employees at all levels. In order to successfully implement and utilize an IPT, the Under Secretary of Defense of Acquisition, Technology, and Logistics (USD AT&L) in the 1999 paper "Rules of the Road: A Guide for Leading Successful Integrated Product Teams Revision 1" outlines six guiding principles for every IPT to follow. By ensuring the correct structure is in place before implementing an IPT, the success of the IPT and the buy in from the employees can be increased.

First, chartering, launching, and initiation enable the IPT to receive the best possible start. The charter defines the mission and purpose of the IPT as well as identifies the IPT customers, outcome product, team member's roles and responsibilities and timeframe for the IPT (USD AT&L 1999). Although the charter is drafted by the team leader, every member should read, understand, and endorse the charter before it is approved by upper management. Launching the IPT involves ensuring each team member is properly trained in the workings and responsibilities of an IPT (USD AT&L 1999). Training ensures each team member has the same baseline knowledge into the workings of an IPT, enabling everyone to know his/her IPT responsibility, which allows the IPT to immediately begin work. Finally, to initiate the IPT, a Plan of Action and Milestones (POA&M) should be established. The POA&M is a measurement tool accompanying the charter to provide a more in depth understanding of IPT activities, key dates, and deliverables (USD AT&L 1999). By properly chartering, launching and initiating an IPT, a successful foundation for the IPT can be established.

Goal alignment is the next guiding principle from USD AT&L. Team member goals and objectives should be consistent with the overarching project goals (USD AT&L

1999). Performance feedback should be established between team members and his or her functional organization. Ideally, individual performance feedback should occur between individual team members and the team member's supervisor to ensure everyone is working at the optimum level (USD AT&L 1999). Additionally, whenever possible, the IPT lead and management should publicly recognize individual team member accomplishment which will aid in the development and success of high-performance IPTs (USD AT&L 1999).

Open discussions with no secrets ensures all facts about an issue are transparent and understood by all team members. When team members feel heard and perceive their contributions matter to the outcome of the IPT, they are more likely to take ownership of the IPT which is critical to an IPT's success (USD AT&L 1999).

Next, the IPT should ensure it has empowered, qualified team members. In order to successfully empower team members, leadership must allow team members to speak for their superiors or if not possible, specifically outline the limits of empowerment (USD AT&L 1999). The IPT should understand each team member's empowerment limitations. For empowerment to be successful, team members must remain in constant communication with their superiors and ensure the superiors' statements are unwavering and sound, barring the discovery of new information. In order for leadership to feel comfortable empowering team members, team members must be qualified having the proper KSAs and training, and have the proper attitude and mindset towards working in an IPT (USD AT&L 1999). Qualified team members are "current in their functional area, knowledgeable in the mission and organization they are representing, and educated and trained in the use and participation of IPTs" (USD AT&L 1999, 13). For the IPT to operate successfully, it is vital that team members and superiors understand from the onset that the agreements reached at the conclusion of the IPT are binding, permanently implemented products (USD AT&L 1999). Creating an implemented product will add validity to the IPT and increase team member buy in and participation.

The IPT should be composed of dedicated, committed, proactive team members. The minimum number of essential personnel should make up the IPT with no extraneous team members in order to enhance communication and trust through the IPT. Each team

member is expected to fully participate in IPT activities and team members. When additional expertise is required by the IPT, personnel from other organizations may be included in the IPT for as long as required (USD AT&L 1999).

Issues or concerns that arise in the IPT should be raised and resolved as early the earliest possible opportunity. First, the IPT should strive the internally resolve the problem and if necessary, may need to seek additional functional expertise. The issues should be addressed during team meetings to ensure openness and transparency for all team members. If the issue is unable to be resolved by the IPT, the team lead should continue to raise the issue up the chain of command until a resolution has been reached (USD AT&L 1999). By successfully creating an IPT from the permanent and contingent workers, the shipyard can increase the work force's personal commitment to the shipyard and increase the human capital value in each worker.

B. RESISTANCE TO CHANGE AND HOW TO TRANSITION TO A HIGH-VALUE-BEST-VALUE SYSTEM OF SYSTEMS

A change in culture and business practices brings with it fear of the unknown. This fear of the unknown manifests itself in many different ways: a resistance to change, a closed-minded view to proven best practices, or a desire to maintain the status quo. The initial transitions to a HVBV SoS will likely encounter resistance from the shipyard as well as from the contractor. The HVBS SoS will challenge the status quo of the shipyard. The government shipyard employees are likely to be reluctant in accepting the contractor as the expert in the contracted field. By accepting the contractor as the subject matter expert, the shipyard may feel that control over the process and end product has been unnecessarily released, creating unease in the shipyard. Additionally, the HVBV SoS approach causes the government anguish in having to relinquish control over risk mitigation due to its highly visible, important nature.

The best way to implement the “best value” portion of the HVBV SoS is to begin at the subcontractor level. By starting with small contracts, both in scope and price, the shipyard and contractors will feel they have less to lose if the “best value” selection does not work as intended. If “best value” selection proves profitable and worthwhile for both

the shipyard and contractor, the prime contractor will be more accepting of the terms and larger contracts in price and responsibility can be assigned using “best value.”

The high value portion of the HVBV SoS will streamline the workload and increase efficiencies in the shipyard. Some workers may feel threatened by these efficiencies and feel his or her job is in jeopardy, causing a reluctance to accept the HVBV SoS. Additionally, distrust or simply not having a previous working relationship between the permanent and contingent workforce may initially cause friction in the IPT creating a less than optimal product. Two solutions can address this problem. First, the IPT can initially be formed on smaller, easier projects. Demonstrating the IPT’s worthiness to both the permanent and contingent worker will encourage overall acceptance of the new practice. Additionally, education is the second key to overcome IPT reluctance. By ensuring the permanent workforce that their jobs are secure, the acceptance of IPTs will increase. Additionally, by training the permanent and contingent workforce in the interworking and intricacies of an IPT, team members will feel an increased sense of belonging and value in their role in the IPT. Training will increase IPT participation and once the cultural norm of permanent and contingent workers working independently is changed, IPTs will be viewed as commonplace and an opportunity to freely exchange views and ideas to create the best possible product. Additionally, training and IPT experience will also directly benefit the contingent workers by increasing their KSAs and work experience. The contingent worker now holds a more robust resume and may be eligible for jobs not previously available due to lack of training or experience. Furthermore, by participating in the IPT, the contingent worker has the opportunity to explicitly demonstrate their value to shipyard’s management leading to the potential to be hired as a permanent worker.

By employing a HVBV SoS, the shipyards and the contactors will no longer view their relationship as strictly contractual, but a relationship based on mutual need and respect for each other. The contractor will desire to perform the best job possible knowing their past job performance impacts any potential follow on contracts. The shipyard will receive a better, on-time product at a more reasonable and transparent cost.

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VIII. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this thesis was to investigate and propose a solution to increase efficiencies in the current public shipyard architecture, how the shipyards award contracts, and relationship between the permanent shipyard workforce and the contingent shipyard workforce. This chapter addresses the research questions posed in the Introduction in Chapter I. Each research question is evaluated and answered individually below. Additionally, recommendations for further study in human capital management and the High-Value-Best-Value System of Systems are addressed at the conclusion of the chapter.

A. CONCLUSIONS

(1) Research Question 1

The first research question posed pertained to the effectiveness of the different types of workers:

What are the impacts of permanent and contingent workers in the private sector as well as in public shipyards on work effectiveness?

Chapter II provides a detailed discussion of the different types of workers, permanent and contingent, in the private sector as well as in public shipyards. Shipyards and the private sector utilize permanent workers to boost the productivity and profitability of the company. This productivity and profitability boost occurs because permanent workers have a greater feeling of company loyalty due to the company investing in the worker's KSAs and allowing for a worker to experience a sense of flexibility and job security because of the standard work agreement. The use of a contingent workforce allows a shipyard to remain agile to changing workload conditions. Additionally, contingent workers are used to provide immediate access to KSAs not available in the permanent workforce and help alleviate the overload of work experienced by the permanent workforce during heightened work season, increasing individual worker effectiveness.

(2) Research Question 2

The second research question addressed managing the different types of workers:

How can managing human capital be used to improve the permanent and contingent workforce human capital yield in public shipyards?

Chapter II discusses human capital management. The proper management of human capital is vital to ensure the organization's missions and goals are achieved. Additionally, when implemented properly, human capital management can increase the return of each individual employee for the company. Shipyards can begin by viewing each individual employee as an asset and not simply a means to cut costs. By investing in an employee's KSAs through the proper establishment of competencies, providing proper mentoring and career advice, providing the proper incentives and rewards for outstanding performance, and allowing the employee to strike the correct balance between his or her own personal and work life, the company proves to the employee they are invested in them. This employer commitment in turn causes the employee to work harder for the company, increasing his or her human capital yield.

(3) Research Question 3

The third research question posed addressed the architecture of the current shipyard:

How does the current architecture of a public shipyard reduce the effectiveness of permanent shipyard workforce and the contingent shipyard workforce?

Chapter III provides the background information for human capital management and discusses high level organizational structure of the shipyards citing Pearl Harbor Naval Shipyard as an example. The organizational architecture of the shipyard causes each department to act alone in performing specific shipyard tasks. This organizational structure reinforces an approach to managing workers that does not favor the spirit of human capital but rather on a very outdated interpretation of employees who are focused on performing the work at hand. By grouping individuals into large like skilled departments, the overall effectiveness of the shipyard workers decreases. If the tasks and

workload are not properly managed, schedule delay and cost overruns due to overtime work can easily occur which decreases worker effectiveness.

Chapter VI provides a detailed examination of the current shipyard system architecture. Currently, the public shipyards are composed of three interacting systems: the shipyard/permanent employee system, the shipyard/contingent worker system, and the union/contingent worker system. These three systems have a complex interaction and are architected in a way that does not promote the effective use of the permanent and contingent shipyard workforce. Instead of encouraging the permanent worker and the contingent worker to utilize each other's KSAs to solve problems and tasks, the workers are stovepiped to work independently. By not openly sharing ideas, experiences, and collaborating together in a group setting, the workers are limiting their potential effectiveness.

(4) Research Question 4

The fourth research question posed pertained to new improved shipyard architecture:

How might the current shipyard model be improved to decrease the number of late availabilities delivered by the shipyard?

Chapter VII discusses a new architectural approach to shipyards, a High-Value-Best-Value (HVBV) System of Systems (SoS). The HVBV SoS can be decomposed into two parts, the practice of "best value" and the practice of high value human capital management. The "best value" practice would require the shipyards to change their current contracting strategy from a "best price" selection to a "best value" selection. By selecting the contractor based on the highest performance at the lowest cost, the shipyards are able to transfer the risk to the contractor, and receive a better product in the given timeframe. The "best value" practice has been proven effective by Arizona State University's Dean Kashiwagi's Performance Based Studies Research Group. Additionally, the model executed in Chapter VII section B.2 showed the U.S. Navy could realize a potential average cost savings of \$4.98 million per availability.

Chapter VII section B.3 discusses the proposed high value system of systems architecture. By allowing the permanent and contingent workers to join together to form an IPT, the workers will feel a sense of pride, ownership, and empowerment in their tasks. Employees' unspoken knowledge will be openly shared, bolstering an unrestricted exchange of information between all team members, increasing the effectiveness of individual team members and the team as a whole.

B. RECOMMENDATIONS FOR FURTHER STUDY

Throughout this thesis, the author provided a solid foundation for the management of human capital, the background of the "best value" and high value management system of systems approach. In the future, using the background provided and the proposed HVBV SoS architecture, a case study is warranted to quantitatively determine the actual cost savings and benefits to the U.S. Navy. The ideal candidate for carrying out the HVBV SoS case study is a low level subcontractor due to the relatively small tasks and funding associated with subcontractors. Prime contractors are unlikely to participate in a case study due to the potential risks in both cost and performance. Subcontractors operate in smaller contracts and will be able to realize the effects of the HVBV SoS quicker than a prime contractor would see. By conducting multiple small case studies, the benefits or drawbacks of the HVBV SoS can be realized. The outcomes of the case studies can lead to further iterations of the HVBV SoS model in order to optimize the shipyard architecture and increase the human capital yield of shipyard employees.

Some of the questions for further study and for case study research are:

1. What are other means, besides the utilization of an IPT, which can be used in a shipyard to improve the permanent and contingent workforce human capital yield?
2. How can the HVBV SoS be scaled to fit large shipyard contracts in both scope and price?
3. What are the policies and procedures needed to implement a "best value" contracting strategy?

APPENDIX A. CONTINGENT WORKERS

The contingent workforce can be further segregated into four different subcategories: independent contractors, on-call workers, temporary help agency workers, and workers provided by contract firms (Bureau of Labor Statistics 2005). Independent contractors are usually identified as self-employed contractors, consultants, or freelance workers. Companies must be careful not to classify contractors, consultants or freelance workers as employees. The legal ramifications for mischaracterization can produce negative consequences for employees. Three tests were developed by the judicial system to determine a worker's status: the common-law test, the economic realities test and a hybrid test fusing elements from the two previous tests.

The common-law test states an employment relationship exists if the “employer has right to control work process, as determined by evaluating totality of circumstances and specifics factors” (Muhl 2002, 6). Factors such as supervision, skill level, payment method, which party supplies the working supplies and materials, the exclusivity and tenure of the working relationship as well as each party's intent is used in the common law test (Muhl 2002). For example, under the common law test, a worker is an employee if the employer supervises the worker. The worker is not an employee if the work is done without supervision.

The economic realities test is similar to the common-law test but concentrates on if the worker's employment is dependent on another individual's business. The economic realities test determines that “employment exists if individual is economically dependent on a business for continued employment” (Muhl 2002, 6). For example, a worker is considered an employee under the economic realities test if the worker has no personal investment in the work facilities and equipment. Conversely, the worker is considered an independent contractor if he/she has considerable investment in the facilities and equipment (Muhl 2002).

Finally, the hybrid test defines employment relationship as being “evaluated under both common-law and economic reality test factors, with a focus on who has the

right to control the means and manner of a worker's performance" (Muhl 2002, 6). Ideally, the hybrid test combines the general and specific factors of each test to create a more all-encompassing determination of employment (Muhl 2002).

On-call workers are employed on an as-needed basis. On-call workers may be employed over the span of multiple days or weeks at a time, or can be for a shorter duration of a day or two (Bureau of Labor Statistics 2005). Temporary help agency workers are employed by a temporary help agency to perform work for a given company. Finally, workers provided by contract firms are employees hired by a company and contracted to work for another company, and are typically employed for longer periods of time and work at the customer's jobsite (Bureau of Labor Statistics 2005).

The four subcategories of contingent workers can all be employed by a company that pays them to work through non-standard work agreements. A non-standard work agreement constitutes any contract between a worker and an employer that deviates from the permanent company employee's contract. Non-standard work agreements, like standard work agreements, vary among companies and employees. The length of the durations of work, employee benefits, employee management chain all vary in non-standard work agreements. Non-standard work agreements are significantly shorter in length than the typical permanent employees. The contract varies in length between a few days to a week, months, or even years.

According to Cohany, (1995) the independent contractors, the largest of the four alternative work categories, are workers who self-identified as working as independent contractors, consultants or freelance workers. Independent contractors work for themselves and are responsible for obtaining clients, ensuring the work is properly executed, and running all business operations. Independent contractors may have employees or may work alone, may have one or multiple clients, and may or may not have an incorporated business. These workers are either self-employed or are wage and salary workers (Bureau of Labor Statistics 2005).

In February 2005, independent contractors accounted for 7.4 percent of the employed U.S. workforce (Bureau of Labor Statistics 2005). Compared to the permanent

workforce, independent contractor's jobs are skewed toward highly skilled fields (Bureau of Labor Statistics 2005). Specific occupation fields seem to be segregated by gender. Men acting as independent contractors include management, business or financial operations occupations; sales and related occupations; and construction and extraction occupations. For industrial jobs, male independent contractors are found in construction, financial activities, and professional and business services. Historically, women as independent contractors work mainly in the service industry—cleaning, child care providers and hairstylists—the sales industry and in professional specialty occupations (Cohany 1995). The typical independent contractor is satisfied with his/her job and is their employment option of choice. Less than 1 in 10 independent contractors stated they would prefer to have a work agreement like a permanent employee (Bureau of Labor Statistics 2005).

Characteristically, independent contractors are dramatically different from other types of contingent workers. According to the February 2005 BLS CPS, the typical independent contractor is a white man of middle age or older. Women accounted for one third of all independent contractors; and only five percent of all independent contractors were African American (Cohany 1995).

Additionally, independent contractors break into two subcategories with regards to hours worked: those who work less than the permanent worker and those who work more. The independent contractor who works less than the standard 40 hour work week of permanent employees is normally older aged, or a woman (Cohany 1995). The women independent contractors only working part time —nearly 50 % of all women independent contractors—is double that of their permanent employee's counterpart (Cohany 1995). On the other end of the spectrum are the independent contractors who work more than 48 hours a week, which was more than double the amount of permanent employees who work 48 hour weeks (Cohany 1995).

The next subcategory of contingent workers is on-call workers. On-call workers are temporarily hired to perform services when needed by a company. Their work duration can range from several days or weeks in a row, usually only working part-time (Bureau of Labor Statistics, 2005). Across the four public shipyards in 2007, seasonal,

borrowed and apprentice workers or “on-call” workers accounted for 10% to 22% of the average workforce composition (Riposo et al. 2008). Also, Puget Sound Naval Shipyard and Intermediate Maintenance Facility in 2013 employed 921 seasonal workers (Friedrich 2013).

On-call workers tend to be slightly more women than men. Women cited personal reasons such as responsibilities for young children or sufficient income from a working spouse whereas men cited economic reasons such as poverty and requiring the extra income for their on-call work (Cohany 1995). In the population of woman on-call workers, over half of the women had at least one child under 18 years of age and half of all the mothers had at least one child under the age of 6 (Cohany 1995). On-call workers tend to be under the age of 25 or over the age of 64 (Cohany 1995). In general, on-call women have less education compared to permanent employees. Only 22 percent of on-call workers hold a college degree—seven percentage points less than permanent workers (Cohany 1995). On average, on-call employees worked 25.9 hours, drastically less than the permanent employee’s standard 40-hour work week (Cohany 1995).

The occupations held by male on-call workers are typically in blue collar jobs - operators, laborers, and craft and repair jobs (including carpenters, electricians and plumbers). Women on-call workers hold jobs primarily in service occupations (clerks and cashiers) and professional specialty occupations (teachers and nurses). The majority of on-call workers would prefer permanent employment (Cohany 1995).

The next subcategory of contingent workers is temporary help agency workers. Temporary help agency workers also referred to as “temp workers” are the most well-known type of contingent workers account for 0.9 percent of all employment in February 2005 (Bureau of Labor Statistics 2005). However, in 2007, temporary workers account for 1% or less of the average workforce composition across the four public shipyards (Riposo et al. 2008). For general office support, the temp agencies perform background checks, hire the workers, and often train the workers. Client companies contact the temp agencies with their desired position need and time duration and the temp agency provides a worker with the prerequisite KSA’s to fill the position. The client company then pays the temp agency who in turn issues a paycheck to the temp worker (Cohany 1995).

The standard profile of temp workers is young women and a member of a minority group. One fourth of all the temp workers are under 25 and over 60% of temp women workers have a child under 18. Additionally, over half of the mothers have a preschooler. Temp workers are less educated than the other types of contingent workers. 14% of all temp workers have not finished high school and just 20% of temp workers have a college degree. Despite having the word temporary in the job title, nearly four fifths of temp employees work at least 35 hours a week (Cohany 1995). Among the four types of alternative work arrangements, temporary help agency workers were the least satisfied with their job. Over half, 56 percent, stated they would rather work in a permanent job (Bureau of Labor Statistics 2005).

Two thirds of temporary help agency workers held a position in clerical and machine operations. Additionally, gender is the main driver for the job differentiation in temp workers. Approximately half the men worked in machine operations and approximately half the women worked in clerical positions (Cohany 1995). When compared to permanent workers, temporary help agency workers held jobs in manufacturing and processional and business service industries (Bureau of Labor Statistics 2005).

Finally, the last subcategory of contingent workers is workers provided by contract firms. Two specific criteria must be met to be classified as a contract company employee: the work is performed on the client company's job site and the individual only works for one client company at a time (Cohany 1995). Workers provided by contract firms are the smallest of the four alternative work agreement group totaling 0.6 percent of total employment in February 2005 (Bureau of Labor Statistics 2005).

The client company overseas the daily activity of the contracted employee while the contracted employee's clerical and administrative burden falls to the contract company. Job assignments for contracted employees tend to be the longest among all types of contingent workers and consisted of full 40 hour work weeks. Characteristically, contracted employees tend to be males younger than 35 (Cohany 1995). Additionally, this group has the highest percentage of college graduates—37 percent (Bureau of Labor Statistics 2005). Construction jobs—like positions held in shipyards—made up 12

percent of all contracted jobs (Cohany 1995). Additionally, contracted workers employed in long term contracts with client companies felt a high degree of job security and considered their employment permanent (Cohany 1995).

APPENDIX B. CONTRACTS

Firm-price contracts can be further broken down into four main categories: firm-fixed-price, fixed-price-with-economic-adjustment, fixed-price-incentive, and fixed-price-with-redetermination. In the shipbuilding industry, firm-fixed-price and fixed-price-incentive (firm target) are the most common types of firm-price contracts utilized (GAO 2013).

In a firm-fixed-price, the contractor assumes all of the performance costs and resulting profit or loss responsibility (Federal Acquisition Regulation 2005). Firm-fixed-price contracts are used when fair and reasonable price estimate is able to be determined at the beginning of the project (GAO 2013). The U.S. Navy is obligated to pay the agreed upon price regardless of the final costs of the ship causing the contractor (shipbuilder) to bear the cost risk overruns. The shipbuilder can realize a gain or a loss depending on if the ship is manufactured for less than the agreed upon price. The shipbuilder is responsible to produce a product within the requirements and specifications of the contract at the expected quality level. Firm-fixed-price contracts can provide a direct incentive to the shipbuilder to produce a ship at the expected level of quality in a timely manner (GAO 2013).

Fixed-price-incentive contracts are “a fixed-price contract that provides for adjusting profit and establishing the final contract price by a formula based on the relationship of final negotiated total cost to total target cost” (FAR 2005, 16.4-3). Fixed-price-incentive contracts are commonly used for follow-on ship class contracts (GAO 2013). The fixed-price-incentive (firm target) contract differs from a standard fixed-price-incentive contract by stipulating a specific target cost, target profile, price ceiling, and a profit adjustment formula which is negotiated at the commencement of the contract (FAR 2005). The U.S. Navy has the responsibility to pay the agreed upon fixed contract price but also shares the cost of any cost overruns or underruns with the shipbuilder up to a specified ceiling price. The assumption of cost risk is shared by the U.S. Navy and the shipbuilder up to a set price. Generally, above the ceiling price, the shipbuilder bears the cost risk. Like the firm-fixed-price contract, the shipbuilder is responsible for producing a

product within the requirements and specifications of the contract at the expected quality level (GAO 2013).

Similar to the decomposition of firm-price contracts, cost-reimbursement contracts can be broken down into four main categories: cost-plus-award-fee, cost-plus-incentive-fee, cost-plus-fixed-fee, and cost and cost-sharing (GAO 2013). Cost-reimbursement contracts permit payment of the contractor's incurred costs. At the onset of the contract, an estimate of the total cost and a ceiling price, not to be exceeded by the contractor without the direct approval of contracting officer, is established (FAR 2005). In shipbuilding, the most common cost-reimbursement contract is with incentive fees and typically employed for a class' lead ship (GAO 2013).

Cost-reimbursement contracts with an incentive fees are used when the requirements are unknown or ill-defined at the onset of the project or an accurate project budget cannot be projected usually due to a lack of knowledge in the subject area (GAO 2013). The U.S. Navy bears the risk of a cost overrun. The cost overrun risk holds the U.S. Navy responsible for all the allowable costs incurred by the contractor. Additionally, the U.S. Navy is not guaranteed delivery of a completed project at the end of the contract. Instead, the shipbuilder delivers a good faith effort to complete the desired task within the estimated cost constraints. If the costs by the contractor are kept low (typically achieved by minimizing rework), the incentive fees in the contract may allow a shipbuilder to earn a higher payout fee which could incentivize better product quality (GAO 2013).

APPENDIX C. RISK

The likelihood of occurrence is a relation between pairs of propositions, but not necessarily only those that are related to the occurrence (Keynes 1921). The degree of relation may not be well known and therefore the relation to the occurrence must be in the realm of the possible. Probabilities do not suppose causality between the propositions, only the test of correlation is deemed necessary. The test of what is necessary and also that which is sufficient is a higher test of the relation, but as stated previously, may not imply causality in the modal, conditional, or proximate sense for the sine qua non of causes (Langford 2012).

In the most general sense, the likelihood of occurrence is related to the enactment of functions that carry the potential to satisfy the test of “necessary and sufficient”. In other words, this test posits a logical relation between the propositions expressed by one object that interacts with another object that (at a minimum) appears to result in a function that correlates with performance that is measurable. A proposition is represented by each object with its inherent mechanisms. By design, likelihood expresses a belief structure about a proposition and therefore about the role of that proposition while it interacts with another object (and that other object’s proposition) in the formation and enactment of the function. Rather than formulating an argument that supports the subjective inclinations of an evaluator of risk, the functional performance that derives from the interaction between two objects is objective and measurable within the arguable positions of measurement theory. What the risk evaluator thinks about the propositions is therefore quantifiable through measures and metrics of functional performances related to various actions and events of the objects within the constructs of their logic relation.

The degree (or assessment) of likelihood that a mechanism will perform as indicated by past history or by predictive analysis forms a quantitative basis that increases the objectivity of the propositions that comprise one of the two bases of risk – likelihood that a correlative function is at work and will produce a better or worse situation than is assessed at the time of evaluation. The other basis of risk is that of the

consequence of the various enactments of the function. That an event occurs due to the actions of the function is itself sufficient to determine the consequence of that function. We can know that an event has occurred by analogy with past history and by extrapolating from past history to the present and future time to determine the impacts should the good/bad event occurs.

In the tradition of Lowrance (1976) and Lewis (2006), simple risk (that is deemed harmful) is a function of threat, vulnerability, and damage (Clemens 2008). The threat results from the objects that interact to enable a function; while the vulnerability and damage relate to the consequences from that threat. Consequence is measurable in terms of energy, matter, material wealth, or information (EMMI) and likelihood is measurable in terms of a number that reflects on the relation between the deleterious events that have occurred in the past or are possible to occur in the future. The assessment of the likelihood of those events occurring varies between 0% and 100%, depending on their assessment on an event scale, and then on a temporal scale that relates the events to past, present, and future time. Therefore, the simple expression of risk as likelihood multiplied by consequence is now expressed through the functional performance of correlative actions derived from mechanisms within objects that interact and are related to the dire events that have transpired in the past or are predicted to occur in the future.

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