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THESIS

**SUBMARINE MAN-DAY GROWTH AT
PEARL HARBOR NAVAL SHIPYARD**

by

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June 2020

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SUBMARINE MAN-DAY GROWTH AT PEARL HARBOR NAVAL SHIPYARD

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The objective for this thesis project is to attempt to identify why 688 class submarine Docking Selected Restricted Availabilities (DSRAs) at Pearl Harbor Naval Shipyard (PHNSY) are growing in man-days every year. The intent is to find an objective and realistic means for process improvement for submarine maintenance. This research relies on publicly available financial data gathered from the Navy's Office of Budget (FMB) as well as the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) management and information database. The research is exploratory and seeks to identify similar trends in both availability man-days and financial costs. The research attempts to identify areas that could be driving maintenance growth as well as calls for an increase in data fidelity for future availabilities.

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LIST OF ACRONYMS AND ABBREVIATIONS

688-class	Los Angeles Class
CBO	Congressional Budget Office
CNO	Chief of Naval Operations
COMSUBPAC	Commander, Submarine Force, U.S. Pacific Fleet
DoD	Department of Defense
DSRA	Docking Selected Restricted Availability
EB	Electric Boat
FMB	Office of Budget
GAO	Government Accountability Office
IMF	Intermediate Maintenance Facility
MD	Man-Days
MRC	Maintenance Record Card
NAVSEA	Naval Sea Systems Command
NNSY	Norfolk Naval Shipyard
NPS	Naval Postgraduate School
NWCF	Navy Working Capital Fund
OFRP	Optimized Fleet Response Plan
O-level	Operational Level
OPCYCLE	Operational Cycle
OPINTERVAL	Operational Interval
PACFLT	Pacific Fleet
PHNSY	Pearl Harbor Naval Shipyard
PNSY	Portsmouth Naval Shipyard
SSN	Submarine Nuclear (Attack)
SRA	Selected Restricted Availability
VAMOSC	Visibility and Management of Operating and Support Costs

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EXECUTIVE SUMMARY

This thesis serves as a trend analysis of costs and man-days at both Pearl Harbor (PHNSY) and Portsmouth (PNSY) Naval Shipyards. This is not to serve as a statistical analysis or a report that shows a causation due to the correlations found through the analysis, but rather serves as a reason for the adoption of a simple means to track data at public shipyards. PHNSY and PNSY were selected due to their nearly exclusive work on fast attack submarines, as well as the large informational data set available for specific maintenance periods at the yards. PHNSY was found to have a large number of the DSRA's performed on 688 class submarines while PNSY performed a large number of EOHs on 688 class submarines from 2007–2019.

This trend analysis has discovered a correlation between apprenticeship costs at the shipyards and the growth in maintenance man-days. Specifically, a trend was identified that started in 2014, with yearly man-day growth for DSRA's at PHNSY rising at a suddenly faster rate than previous periods. This shift in man-day growth correlated to the divergence of apprenticeship costs per apprentice at PHNSY when compared to PNSY.

Based on these corresponding events, an extrapolation shows that with conservative estimates, if apprenticeship program costs are being absorbed by DSRA project funds, approximately 30% of the annual growth in DSRA man-days can be attributed to the apprenticeship program. This extrapolation is meant to serve as an illustration of why an objective means of accounting for hours worked on a specific job in a maintenance availability is necessary.

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I. INTRODUCTION

A. PURPOSE

This thesis is meant to serve as a comparison and an analysis of public and private shipyard financial practices in regard to submarine maintenance availabilities. Specifically, this thesis will attempt to address the rise in both cost and man-hours of selected submarine maintenance availabilities for Los Angeles class submarines, as well as compare and contrast costs associated with submarine maintenance at public shipyards.

1. Problem Statement

Examine how cost growth of major submarine maintenance periods has manifested across public shipyards.

2. Research Questions

1. Are cost growths of DSRA maintenance at PHNSY inconsistent with other public shipyards?
2. Is there a fair price comparison of DSRA maintenance performed at private and public shipyards?
3. Are there common financial trends between the 4 public shipyards?

B. OBJECTIVE

The objective of this thesis is to provide an accurate comparison of costs between public shipyards in regard to Los Angeles class submarine maintenance in selected availabilities. This thesis will also attempt to provide analysis of quantifiable factors that could indicate opportunities to improve in resource management for the public shipyards.

C. SCOPE

Previous research, analysis, and thesis projects has limited the scope of comparison in varying degrees. This thesis will focus analysis in the following ways.

1. Selected Availabilities: The selected availabilities analyzed for Los Angeles Class submarines will be limited to DSRAs, EOHs, and PIRA periods. The three maintenance availability types selected is larger than previous analysis but is necessary for this analysis such that trends can be identified across shipyards.
2. Shipyards: All four public shipyards that perform maintenance on Los Angeles Class submarines. These shipyards will be analyzed for their appropriateness to be included in trend analysis. Determinations will be made whether particular shipyards should be included in specific analysis and may be included in some analysis but may be not be included in other analysis.
3. Time: Maintenance availabilities and financial data will be analyzed primarily between the years 2007 and 2018. In some comparisons the time limitations will be lifted to show historical context and trends prior to shifting fiscal practices.
4. Monetary and Personnel Data: All monetary and personnel data analyzed is provided through open source documents available through FMB Navy Budget Justification documents as well as through VAMOSC data libraries.

II. BACKGROUND

A. INTRODUCTION

The purpose of this chapter is to provide sufficient information on previous research and theses to provide context for this thesis analysis.

B. SHIPYARD LOCATIONS

There are four public shipyards and two private shipyards that perform maintenance availabilities on Los Angeles class submarines. The four public shipyards are Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility in Pearl Harbor, Hawaii, Puget Sound Naval Shipyard and Intermediate Maintenance Facility in Bremerton, Washington, Portsmouth Naval Shipyard in Kittery, Maine, and Norfolk Naval Shipyard in Portsmouth, Virginia. The two private shipyards are General Dynamic's Electric Boat in Groton, Connecticut, and Huntington Ingalls Industries' Newport News Shipbuilding in Newport News, Virginia. These locations are where the majority of maintenance is performed; however, some work is performed by some of the shipyards at others of the above shipyards, or at submarine bases, due to dry-dock availability or other contract requirements.

C. MAINTENANCE AVAILABILITIES

Los Angeles class submarines undergo three typical availability types throughout their time commissioned. The three main types of availabilities are DSRA, EOHs, and a PIRA. Typically, each submarine will have a DSRA every 72 months, and this availability will last a nominal 3 months (COMNAVSEASYS COM, 2010). Recent trends in DSRA maintenance availabilities have shown that the average time for completion of a DSRA for a Los Angeles class submarine has increased to over 5 months (CBO, 2019).

EOHs typically occur for Los Angeles class submarines every 10 years and will nominally take 2 years for completion. Major ship upgrades occur during this maintenance availability and are necessary to maintain a modern and highly capable submarine fleet.

PIRAs are hull specific availabilities that are designed to obtain one last deployment out of an aging submarine prior to inactivation of said submarine. PIRAs are typically longer than DSRAAs but faster than EOHs (Chief of Naval Operations, 2013).

While DSRAAs, EOHs, and PIRAs are not the only maintenance periods that a submarine will undergo, they are the typical CNO availabilities that all submarines will nominally experience. Additionally, although there is a large disparity between scope and time required during the different maintenance periods, all three availabilities experience similar pressures to execute on time and trends identified in one availability type can be indicative of trends in other availability types due to the similarity between shipyards and infrastructure/support required for submarine maintenance.

D. COSTS OF SUBMARINE MAINTENANCE

The April 2019 Congressional Budget Office report entitled *Costs of Submarine Maintenance at Public and Private Shipyards* provided analysis of historical costs of DSRA maintenance periods for Los Angeles class submarines between 1993–2017. This analysis was carefully segmented into three time periods that correlated with changes in financial accounting practices as well as a transition period. The report states that in 1999 the Navy began transitioning from a working capital funding (WCF) method at public shipyards to a mission funding method. The transition was completed in 2007, and mission funding was used at all public shipyards. Findings from this report are included in Table 1. The CBO report summarized that the average cost is higher for DSRA maintenance on Los Angeles class submarines at public shipyards, however public shipyards average about 1 month faster than private shipyards to complete a DSRA. The CBO does identify several limitations to their analysis; specifically, that the VAMOS data for cost of shipyards does not match cost of data from other Navy sources. The CBO report corrected costs in VAMOS data to best available, but some inconsistencies could remain. Additionally, at the time of analysis, only one DSRA had occurred at a private shipyard since 2010. The report also identifies that additional submarines could be sent to private shipyards for cost saving measures, but only briefly addresses the time and space constraints held by private

shipyards due to the construction of new Virginia class submarines and the soon to be constructed Columbia class submarines.

Table 1. DSRA Overhauls of SSN-688s, by Period of Funding.
Source: CBO (2019).

DSRA Overhauls of SSN-688s, by Period of Funding			
	Private Shipyards	Public Shipyards	Difference (Percent)
Number of Overhauls			
1993–1998	17	44	n.a.
1999–2006	5	47	n.a.
2007–2017	7	26	n.a.
Total Number of Overhauls	29	117	n.a.
Adjusted Average Cost (Millions of 2018 dollars)^a			
1993–1998	10.7	22.3	-52
1999–2006	26.1	32.9	-21
2007–2017	52.1	53.8	-3
Total Adjusted Average Cost	23.3	33.6	-31
Average Days in Shipyard			
1993–1998	72	88	n.a.
1999–2006	124	104	n.a.
2007–2017	206	171	n.a.
Total Average Days in Shipyard	113	113	n.a.

Source: Congressional Budget Office, using data from the Navy's Visibility and Management of Operating and Support Costs (VAMOSC) system.

DSRA = Docking Selected Restricted Availability; n.a. = not applicable.

From 1993 to 1998, Navy shipyards used working capital funding, and from 2007 to 2017 they used mission funding. The years between were a period of transition between the two types of funding.

a. Costs were adjusted to include overhead activities that the Navy omitted from VAMOSC starting in 1999.

E. MAINTENANCE SCHEDULES AND SKILLED LABOR PERSONNEL

GAO's December 2019 report, *Persistent and Substantial Ship and Maintenance Delays Hinder Efforts to Rebuild Readiness*, identifies several issues that could be major contributors to delays and cost overruns at naval shipyards. These issues include the difficulty in adhering to maintenance schedules due to operational tempo and scheduling

difficulties, as well as the shortages of skilled personnel in critical fields such as welding and ship fitters.

The difficulty in adhering to maintenance schedules is evident in multiple spectrums. The first is explored in-part by Lindle and Wisz's 2019 thesis that describes the process where a large portion of work to be completed in a DSRA is added after "final" approval by the Navy. This is because new work is identified as the ship approaches a maintenance availability. While the new work itself is not individually an issue for the shipyards, it does present opportunities for scheduling problems to arise due to limited resources and space at the shipyards. These late additions of work add both time and cost to the scheduled availability prior to the ship even entering the shipyard. The second spectrum of maintenance overruns is also explored by Lindle and Wisz (2019). Their findings indicate the growth in Man-Hours to complete similar maintenance jobs. For example, their findings indicate that the same job in 2007 took fewer Man-Hours to complete than it does in 2017. The longer hours working on the same or similar jobs was shown by Lindle and Wisz to not be directly linked to hull age, but rather fiscal year. The more recent the maintenance was performed, the longer that maintenance likely took.

The shortage of skilled welders and ship fitters identified by the GAO report in December 2019 is not the first indication of the labor shortage. The GAO report shows that shipyards have increased their hiring rate since 2014, and has resulted in a 22% increase in workers between 2014 and 2019. Shipyards have also increased incentive programs to attract and maintain skilled laborers. The training of a new apprentice takes approximately 5 years, with 4 years as an apprentice before becoming fully productive, however this timeline the Navy hopes to shorten with new training techniques. On the job training is emphasized as a means of shortening the time to train a new worker because of the valuable training experience available outside of a classroom.

The standard process to become a qualified skilled labor at the public shipyards require completion of 4 years as an apprentice. Throughout the apprenticeship, each apprentice spends hours in the classroom and shop as well as receives on-the-job training working on submarine projects under a qualified laborer.

F. SUBMARINE MAINTENANCE JOB PLANNING PRACTICES

The whitepaper produced by Matthew Carreras, *Trust*, outlines the planning process that maintenance periods require prior to the submarine arrives in port (2019). Carreras describes the process on how a submarine maintenance availability is planned. In summary, first the Navy identifies which maintenance jobs will be required during the availability. Once the list of jobs is provided, the shipyard engineers create a time estimate for each job based on previous history of completing the same, or similar jobs. Once this timeline is presented by the engineers, the shipyard management, supervisors, and engineers determine the optimal scheduling for the jobs and provide both a time and budget estimate to the Navy. Several iterations of this process occur prior to the submarine entering the availability.

Carreras goes further and postulates that occasional maintenance jobs are artificially inflated due to either apprentice on-the-job training included in the maintenance job or the downtime between workable jobs are inappropriately charged to maintenance jobs that are not ready to be worked. Carreras does state that the exact hours of a job are not able to be accurately tracked because of the nature in which jobs are performed. Union pressure is the driving force for not keeping accurate time measurements for job completion. Without the accurate accounting of how long and which qualified worker works on a job, future jobs can only be planned for with approximations. Additionally, there is speculation suggested that apprentice on-the-job training is paid for through project funds rather than apprenticeship or shop funds (Carreras, 2019).

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III. RESULTS/ANALYSIS

The first step in this analysis is to identify a suitable means to compare shipyards. To begin, this analysis took a holistic approach to identify which shipyards performed the majority of the common availabilities. The data provided by FMB slightly conflicts with VAMOSC data, nevertheless, to provide for additional independent comparison, FMB data is compared with VAMOSC.

A. COMPARISON OF NUMBER OF AVAILABILITIES PER SHIPYARD

Of the data available through FMB, there were a total of 49 EOHs, DSRAs, and PIRAs that were performed at public shipyards between 2009 and 2019. VAMOSC provides slightly different data, with a total of 59 availabilities at public and private shipyards between 2007 and 2019. The data is presented in Figure 1.

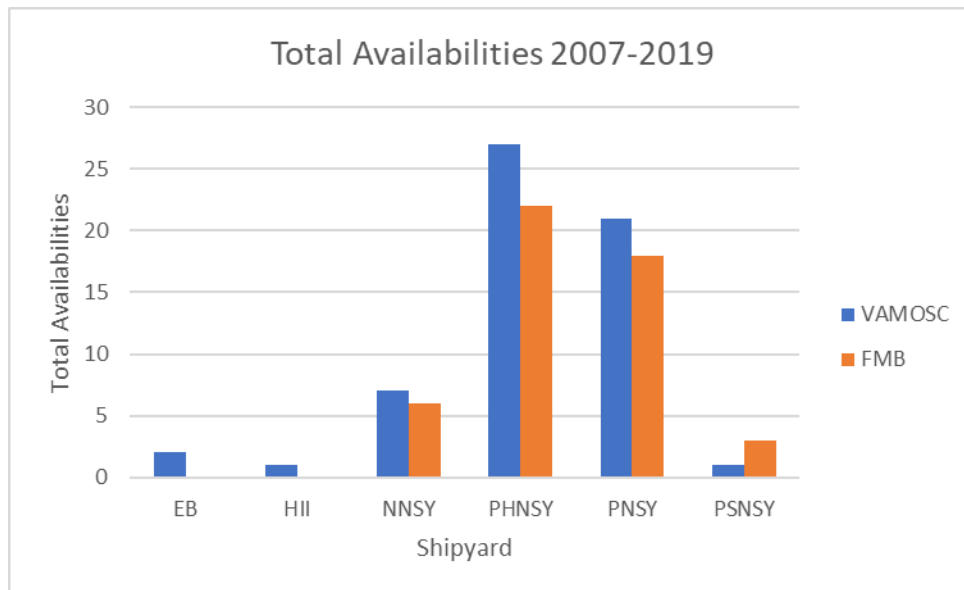


Figure 1. Total Availabilities at each shipyard FY2007–2009. Adapted from VAMOSC (2020) and FMB (2020).

Although Figure 1 shows that the numbers from VAMOSC and FMB are not identical, a conclusion can easily be reached that EOHs, DSRAs, and PIRAs predominantly

occur at either Pearl Harbor Naval Shipyard or Portsmouth Naval Shipyard. Further breakdown of what type of availability happened at each shipyard is provided in Figures 2, 3, and 4.

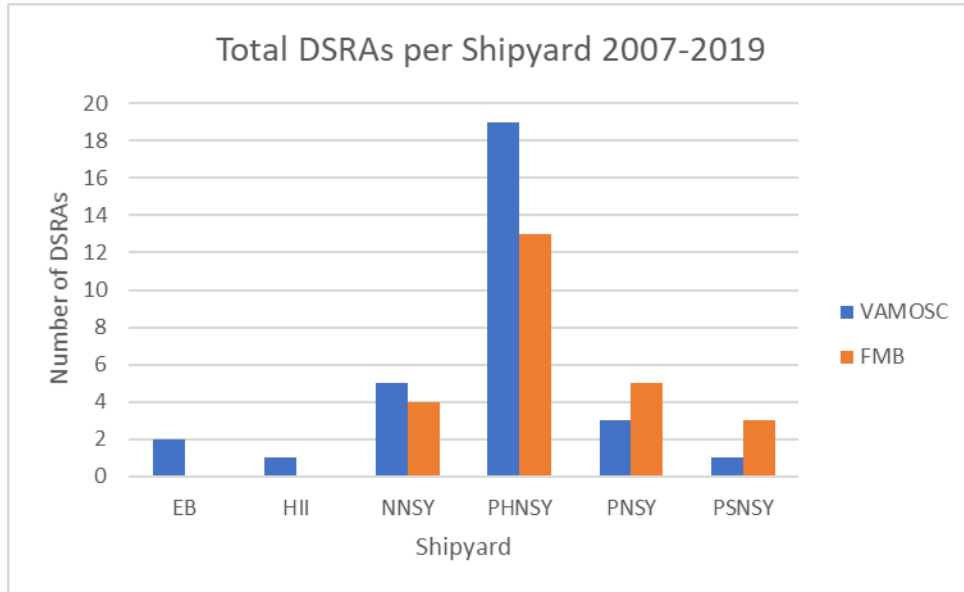


Figure 2. Total DSRAs at each shipyard FY2007-2019. Adapted from VAMOSC (2020) and FMB (2020).

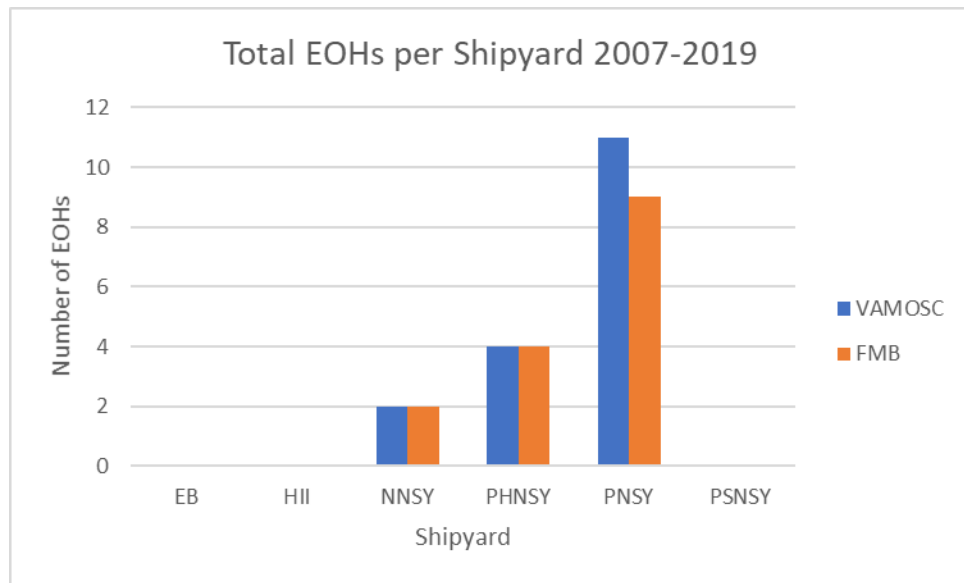


Figure 3. Total EOHs at each shipyard FY2007-2019. Adapted from VAMOSC (2020) and FMB (2020).

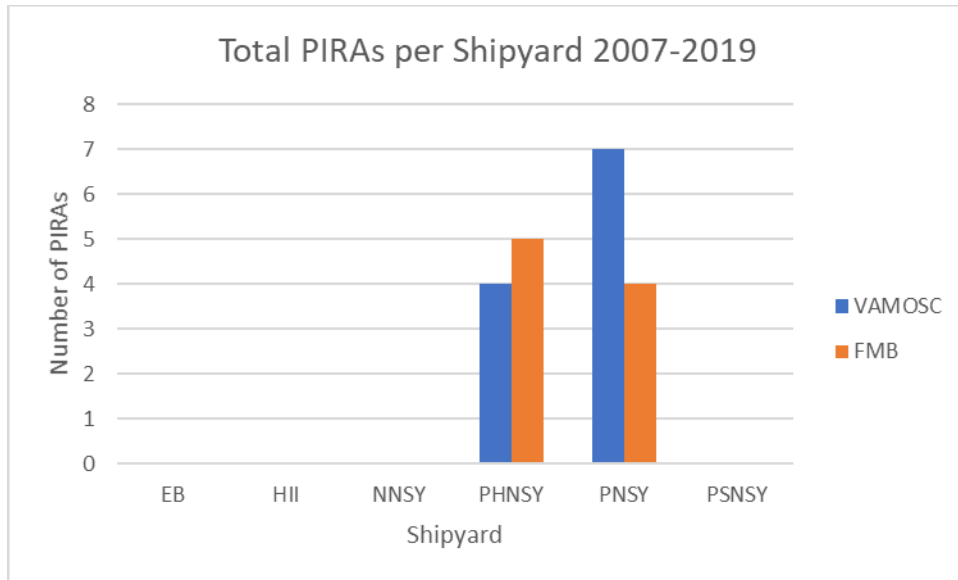


Figure 4. Total PIRAs at each shipyard FY2007-2019. Adapted from VAMOSC (2020) and FMB (2020).

Figures 1, 2 ,3, and 4 show that both VAMOSC and FMB data suggest that an overwhelming majority of DSRAs occurred at Pearl Harbor Naval Shipyard, the majority of EOHs occurred at Portsmouth Naval Shipyard, and PIRAs occurred roughly equally between Pearl Harbor Naval Shipyard and Portsmouth Naval Shipyards.

B. COMPARISON OF AVAILABILITY COSTS

Figure 5 shows how the cost of DSRAs of 688 class submarines have changed since 2007 while Figure 6 shows the cost of EOHs since 2007. Figures 5 and 6 show the steady rise in the price of each availability per year. Figure 7 alternatively shows the apparent sporadic cost of PIRAs since 2007, and is expected to be sporadic due to the hull specific nature of a PIRA maintenance period.

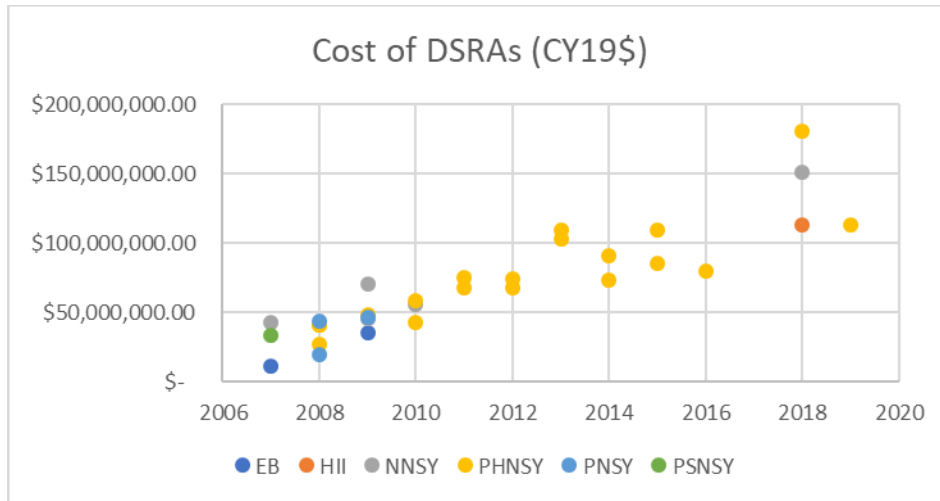


Figure 5. Total cost of DSRAs started and completed between FY2007–2019. Source: VAMOSC (2020).

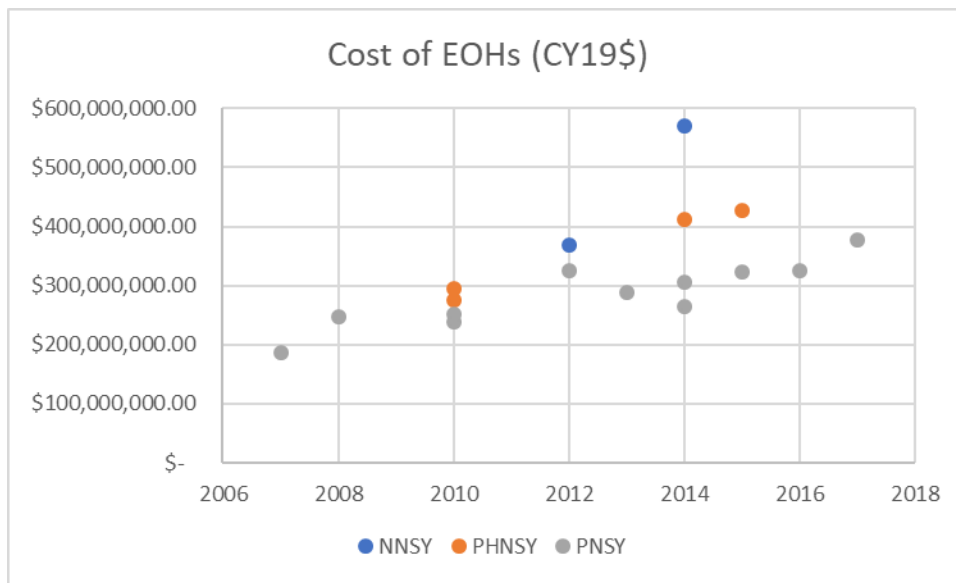


Figure 6. Total Cost of EOHs started and completed between FY2007–2019. Source: VAMOSC (2020).

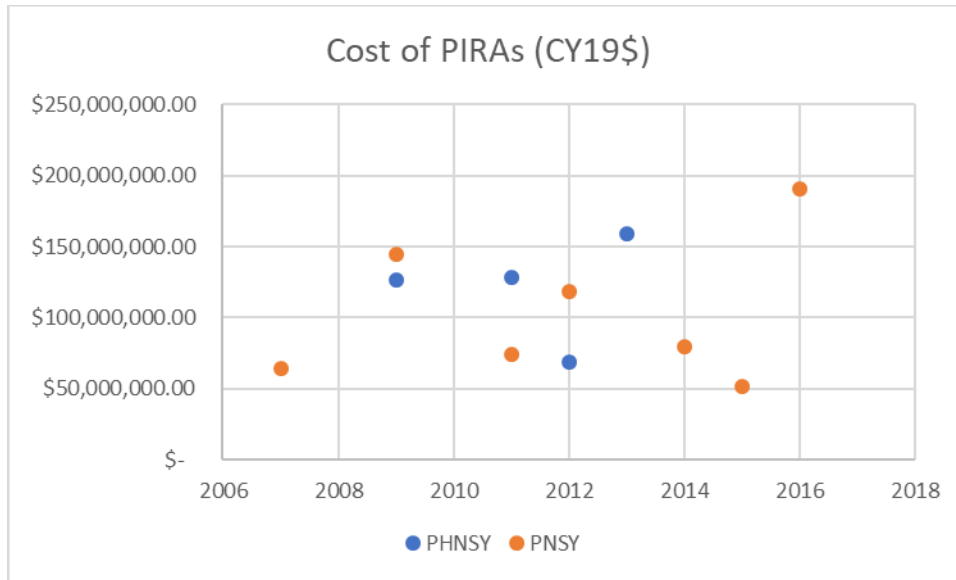


Figure 7. Total cost of PIRAs started and completed between FY2007–2019. Source: VAMOSOC (2020).

C. COMPARISON OF MAN-DAYS

Figure 8 shows how the total man-days of DSRAs of 688 class submarines have changed since 2007 while Figure 9 shows the total man-days of EOHs since 2007. Figures 8 and 9 show the steady rise in the price of each availability per year. Figure 10 alternatively shows the apparent sporadic total man-days of PIRAs since 2007, and is expected to be sporadic due to the hull specific nature of a PIRA maintenance period.

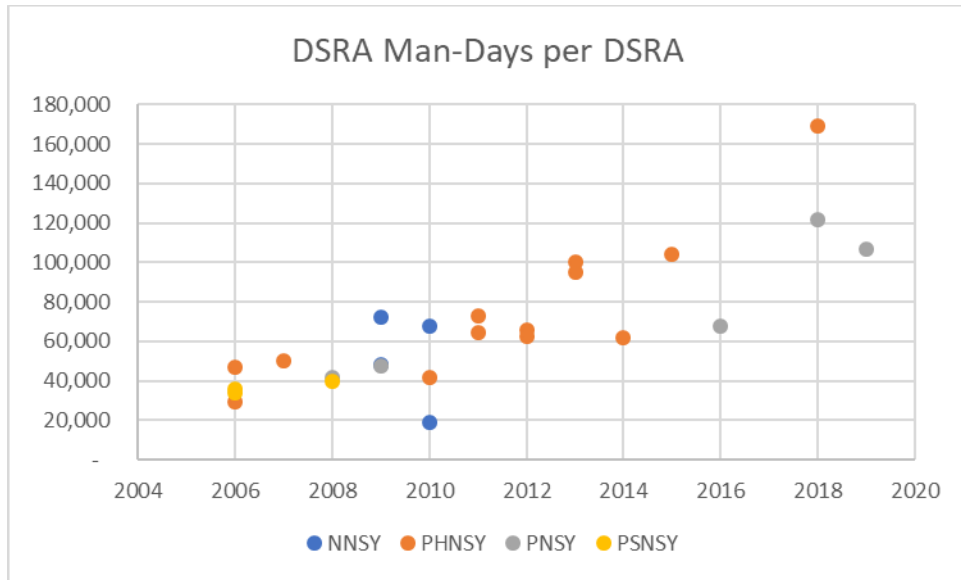


Figure 8. Total man-days of DSRA started and completed between FY2007–2019. Source: FMB (2020).

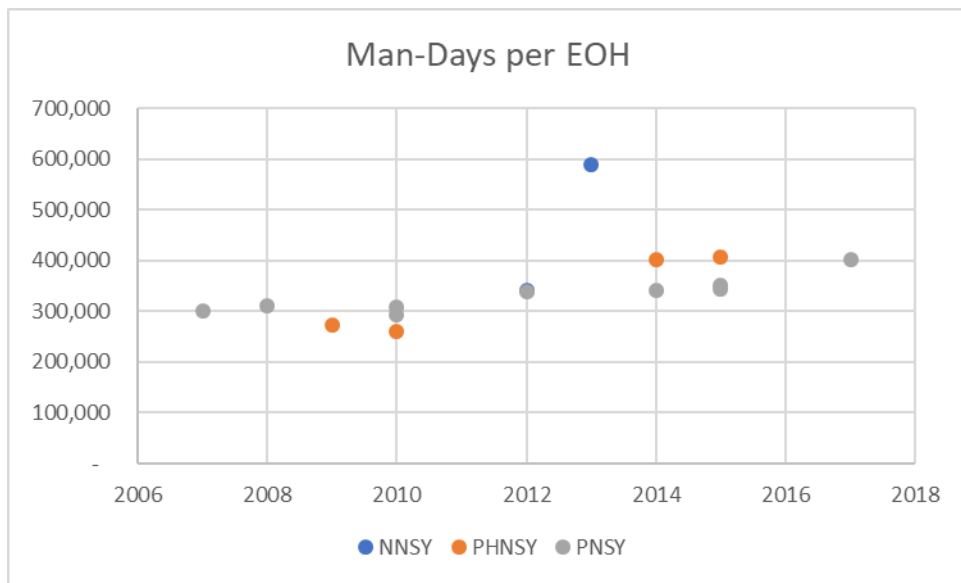


Figure 9. Total man-days of EOHs started and completed between FY2007–2019. Source: FMB (2020).

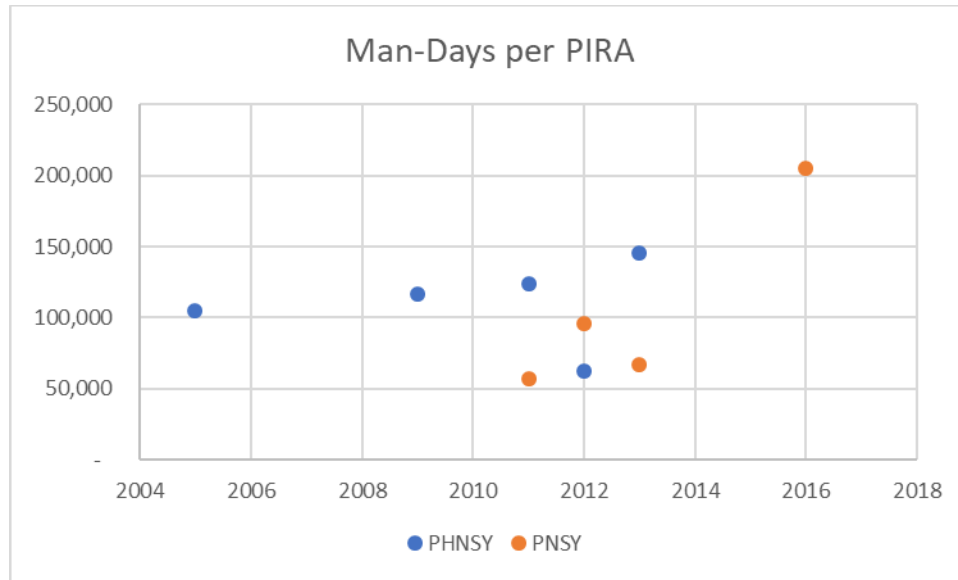


Figure 10. Total man-days of DSRAs started and completed between FY2007–2019. Source: FMB (2020).

Based on the inconsistency of costs and Man-Days of PIRAs between FY2007 and FY2016, PIRAs do not serve as a good availability type to assess cost trends across shipyards. This is consistent with the hull specific requirements nature of PIRA maintenance periods. But, because of the high number of DSRAs that occurred at PHNSY and high number of EOHs that occurred at PNSY from FY2006 to FY 2018, a common trend can be seen. Although the man-days required for DSRAs and EOHs differ in magnitude, a similar upward trend in man-days can be observed for these different availabilities at different shipyards. This similar trend is seen in total costs for the shipyards as well.

D. NARROWING SCOPE TO PHNSY AND PNSY

Because there is a disparity between the types of maintenance items at each shipyard, there are too few data points to perform a meaningful comparison of different shipyards with respect to a single availability type. However, there are a larger number of DSRA maintenance periods at PHNSY and a larger number of EOH maintenance periods at PNSY than any other type of maintenance at the other shipyards. By limiting the number of shipyards to just PHNSY and PNSY I can perform a deeper comparison of labor costs

for these shipyards over time. Figure 11 shows the trend of total direct labor man-days for both EOHs at PNSY and DSRAs at PHNSY while Figure 12 shows the total cost of those maintenance periods.

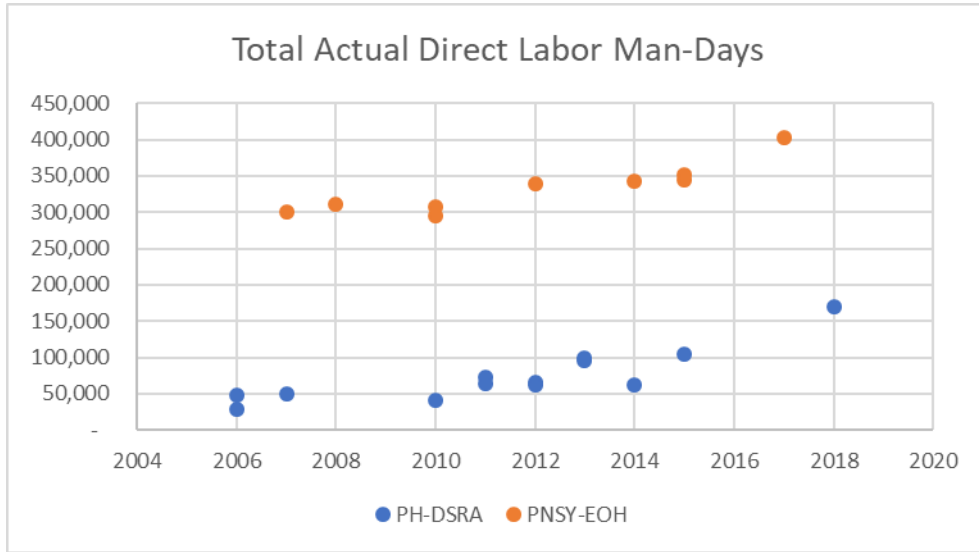


Figure 11. Total Actual Direct Labor Man-Days at PHNSY and PNSY for DSRAs and EOHs. Source: FMB (2020).

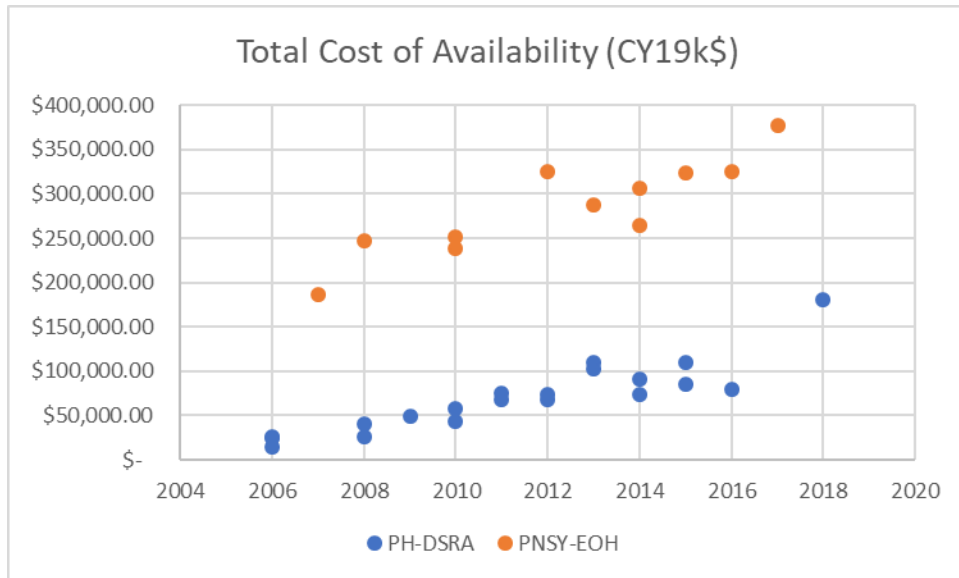


Figure 12. Total Cost of DSRAs and EOHs at PHNSY and PNSY. Source: VAMOSOC (2020).

Figure 13 graphically shows the similar trend in Direct O&M Base money that the PHNSY and PNSY received. This shows a consistent trend in shipyard spending from 2007–2019.

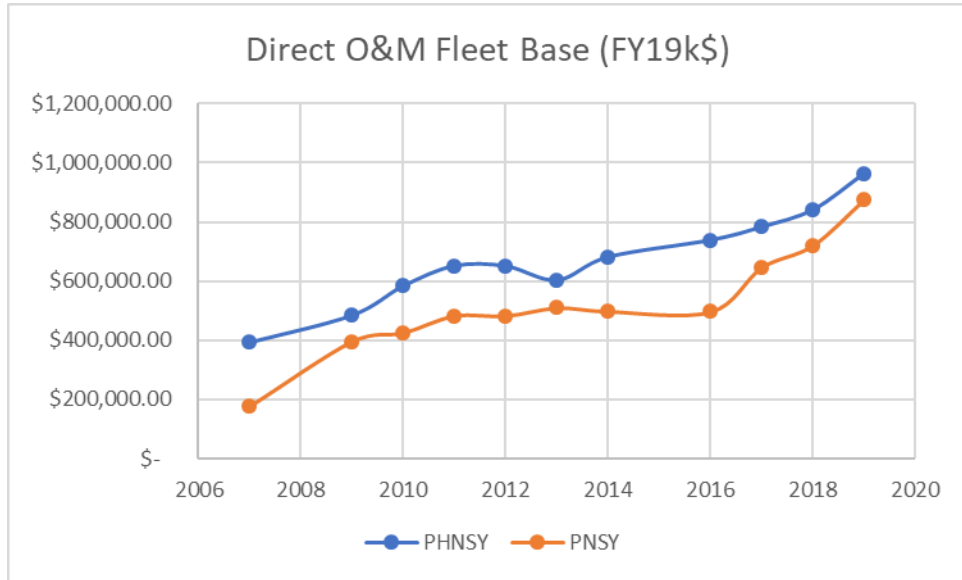


Figure 13. Direct O&M Fleet Base Budget at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

Figure 14 graphically shows the similar trend unit cost per man-day money at PHNSY and PNSY. Unit costs reports the total cost less direct material, direct contract, other direct, and MICON per direct labor man-day delivered. This shows a consistent trend in shipyard costs from 2007–2019.

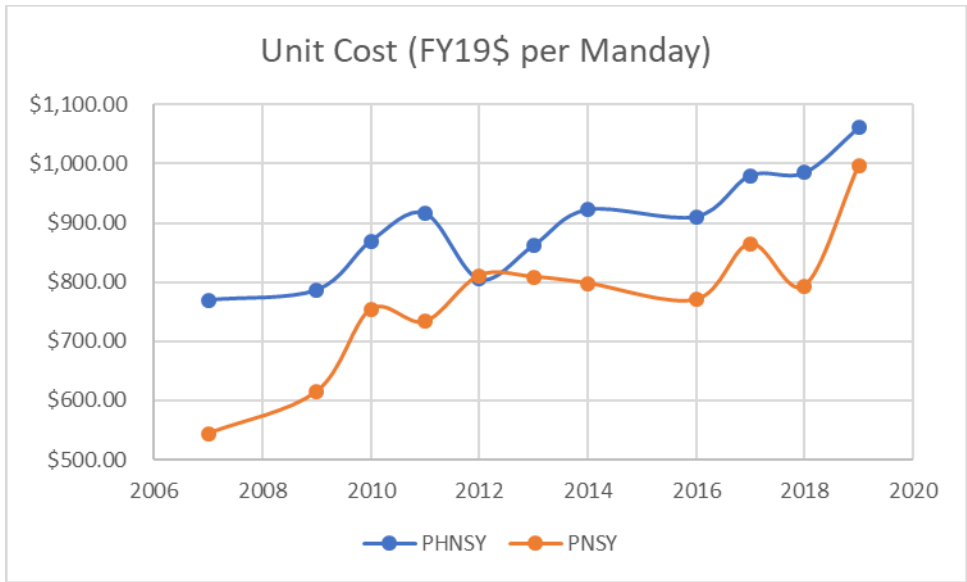


Figure 14. Unit Cost at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

Figure 15 graphically shows the similar trend in direct civilian labor costs at PHNSY and PNSY. This shows a consistent trend in labor costs from 2007–2019.

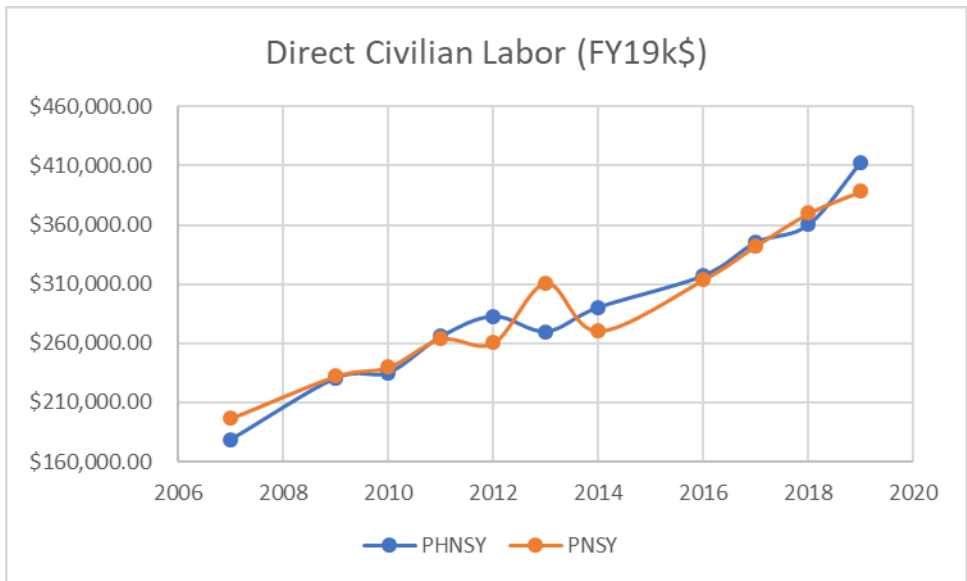


Figure 15. Direct Civilian Labor Cost at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

Figure 16 graphically shows the similar trend in direct material costs at PHNSY and PNSY. This shows a consistent trend in costs from 2007–2019.

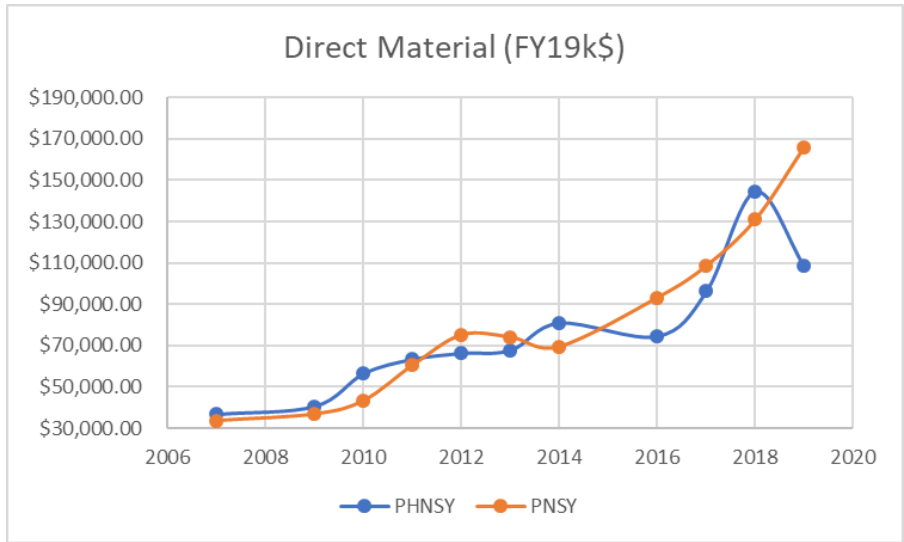


Figure 16. Direct Material Cost at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

Figure 17 graphically shows the similar trend in overhead civilian labor costs at PHNSY and PNSY. This shows a consistent trend in overhead costs for civilian labor from 2007–2019.

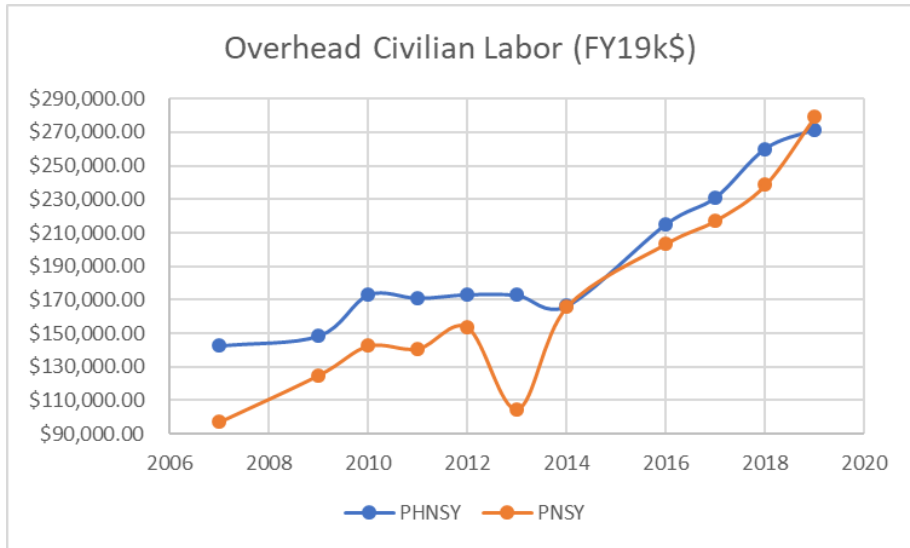


Figure 17. Overhead Civilian Labor Cost at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

Figure 18 graphically shows the similar trend in overhead non-labor costs at PHNSY and PNSY. This shows a consistent trend in overhead non-labor costs from 2007–2019.

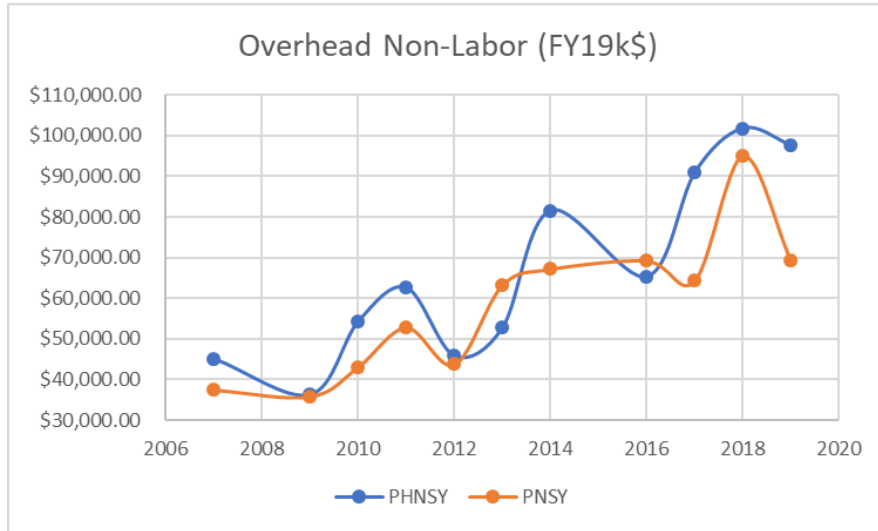


Figure 18. Overhead Non-labor Cost at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

Figure 19 graphically shows the similar trend in mission man-days at PHNSY and PNSY. This shows a consistent trend in workload from 2007–2019.

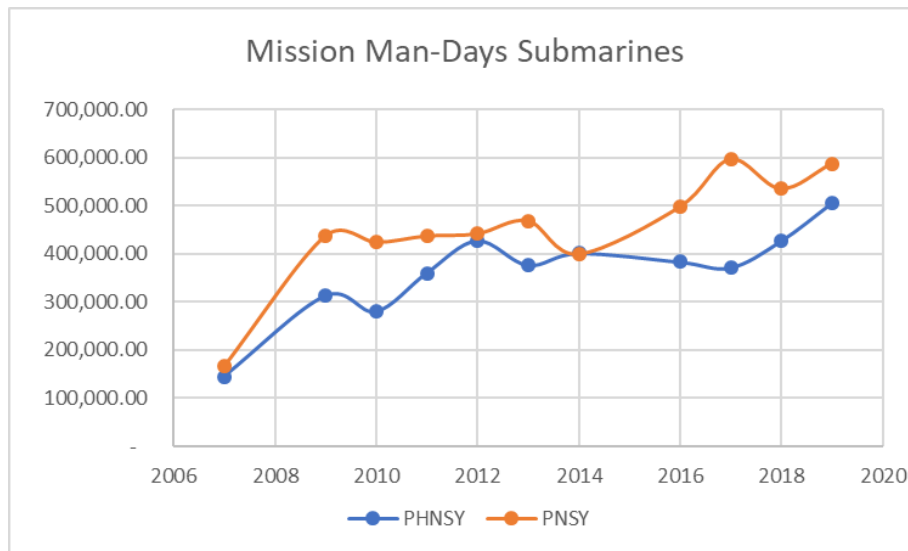


Figure 19. Total Mission Man-Days (submarines) at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

Figure 20 graphically shows the similar trend in civilian end strength at PHNSY and PNSY. This shows a consistent trend in labor force from 2007–2019.

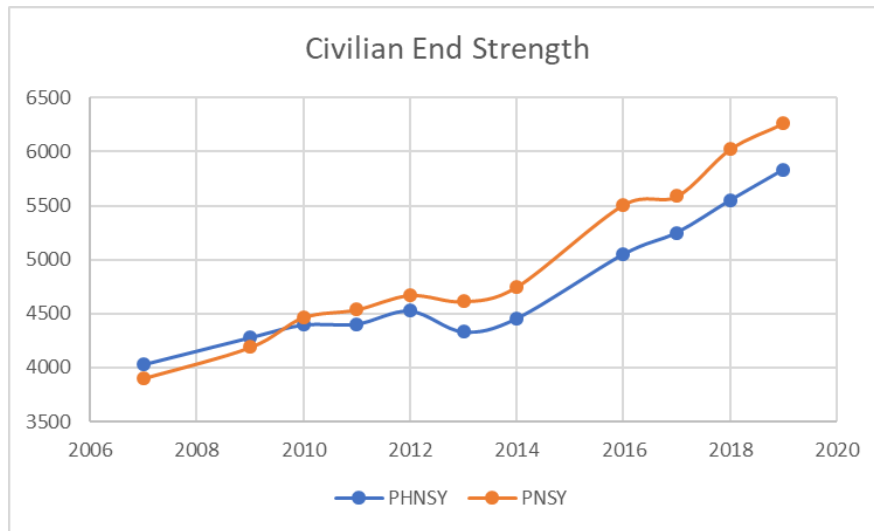


Figure 20. Civilian End Strength at PHNSY and PNSY adjusted to FY19k\$. Source: FMB (2020).

As can be seen with the Figures 11 through 20 above, PHNSY and PNSY have consistently trended together between FY2007 and FY2019. These two shipyards are highly relatable because of their characteristics of nearly exclusive work on submarines, particularly during the maintenance availability periods bound by this thesis. Additionally, when the fiscal categories above are normalized by submarine man-hours worked, a similar comparison can be seen in Figures 21 through 26. This indicates that costs at both PHNSY and PNSY are consistent when normalized to Man-Days worked on submarines. However, although the GAO report claims that shipyards have increased their hiring rate, that rate is not keeping pace with the Man-Days worked at PHNSY or PNSY. In fact, the civilian workforce at both PHNSY and PNSY has increased 45% at PHNSY and 61% at PNSY, but the civilian labor per Man-Day has decreased approximately 81% at both shipyards between from 2007 to 2019. This indicates that either the hiring rate of civilians is not sufficient to maintain the demand for work, or that the Man-Hours that are recorded for submarine maintenance is growing faster than the hiring rate.

Figure 21 plots the similar normalized trend in Direct O&M Base dollars per submarine man-days at PHNSY and PNSY. This shows a consistent trend in funding requirements per man-day from 2007–2019.

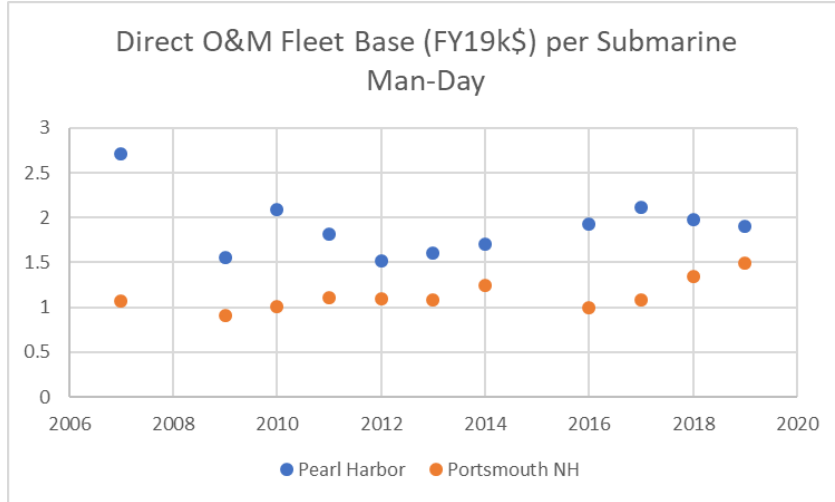


Figure 21. Direct O&M Fleet Base per Submarine Man-Day (FY19k\$/Sub Man-Day). Source: FMB (2020).

Figure 22 plots the similar normalized trend in direct civilian labor costs per submarine man-days at PHNSY and PNSY. This shows a consistent trend in labor costs per man-day from 2007–2019.

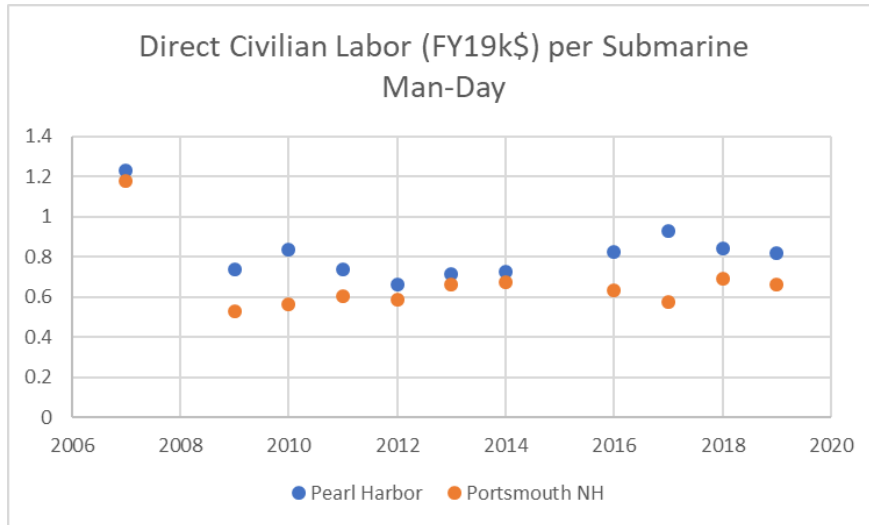


Figure 22. Direct Civilian Labor Cost per Submarine Man-Day (FY19k\$/Sub Man-Day). Source: FMB (2020).

Figure 23 plots the similar normalized trend in direct material costs per submarine man-days at PHNSY and PNSY. This shows a consistent trend in material costs per man-day from 2007–2019.

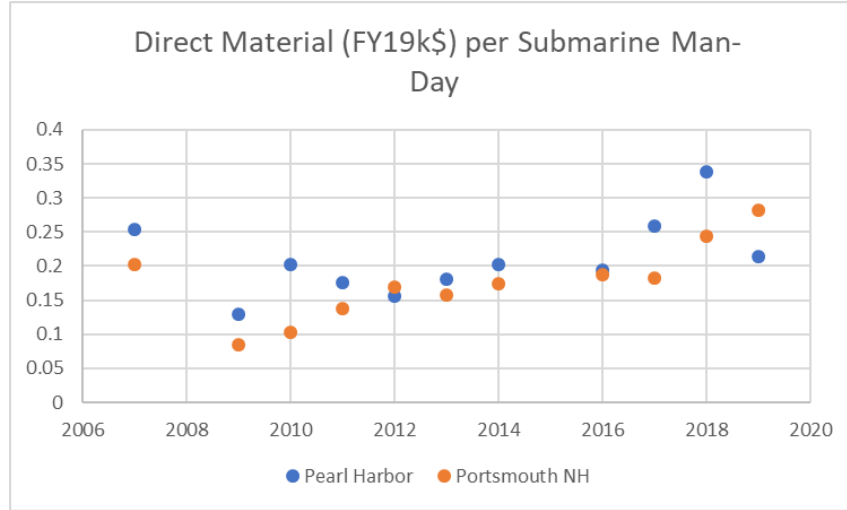


Figure 23. Direct Material Cost per Submarine Man-Day (FY19k\$/Sub Man-Day). Source: FMB (2020).

Figure 24 plots the similar normalized trend in overhead civilian labor costs per submarine man-days at PHNSY and PNSY. This shows a consistent trend in overhead labor costs per man-day from 2007–2019.

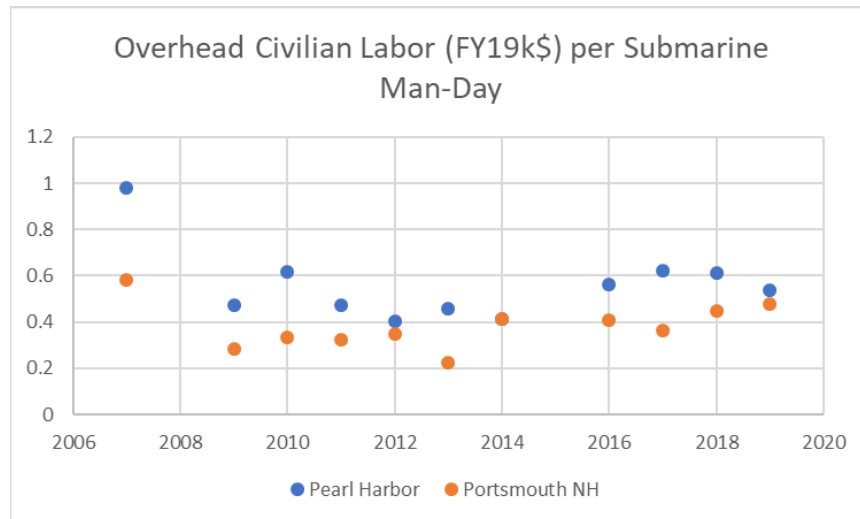


Figure 24. Overhead Civilian Labor Cost per Submarine Man-Day (FY19k\$/Sub Man-Day). Source: FMB (2020).

Figure 25 plots the similar normalized trend in overhead non-labor costs per submarine man-days at PHNSY and PNSY. This shows a consistent trend in overhead non-labor costs per man-day from 2007–2019.

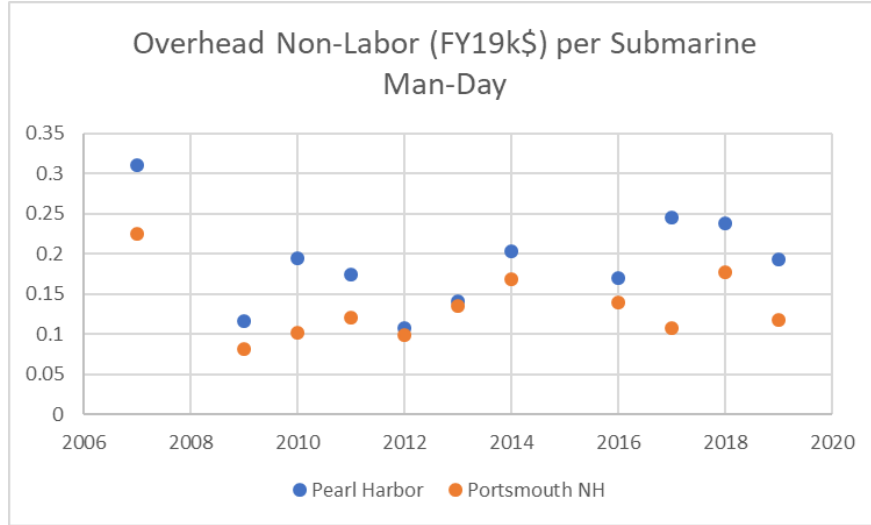


Figure 25. Overhead Non-labor Cost per Submarine Man-Day (FY19k\$/Sub Man-Day). Source: FMB (2020).

Figure 26 plots the similar normalized trend in civilian end strength per submarine man-days at PHNSY and PNSY. This shows a consistent trend in work force per man-day from 2007–2019.

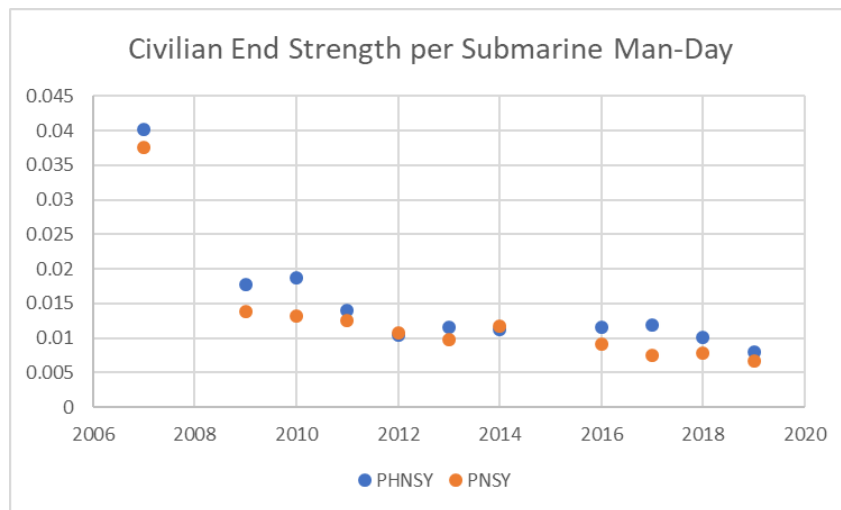


Figure 26. Civilian End Strength per Submarine Man-Day. Source: FMB (2020).

E. COMPARISON OF APPRENTICESHIP PROGRAMS

The following graphs show the total number of apprenticeships and apprenticeship costs incurred at PHNSY and PNSY from FY2007 through FY2018. This data is provided from FMB Budget Justifications.

Figure 27 shows that between the years 2007–2014, PHNSY and PNSY each employed nearly identical total numbers of apprentices.

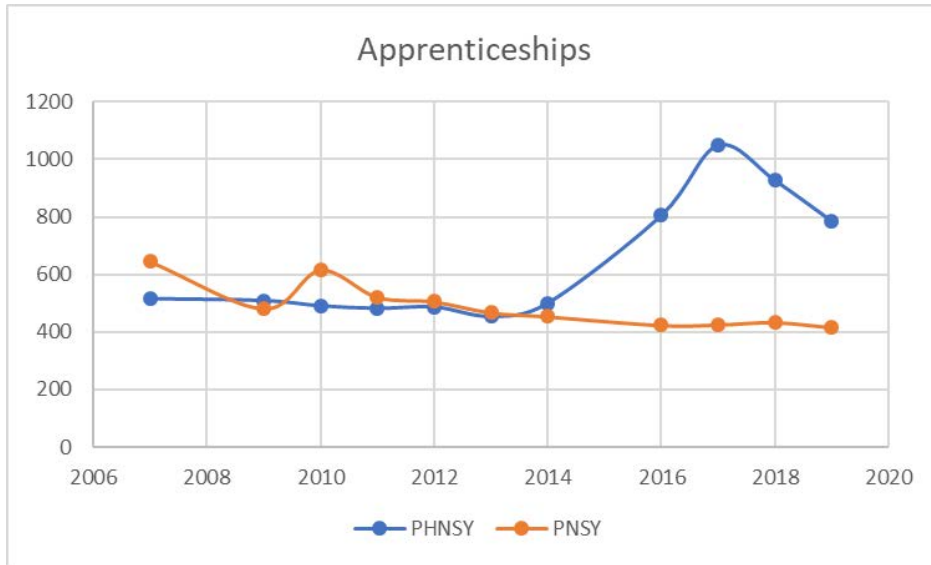


Figure 27. Number of Apprentice Workers. Source: FMB (2020).

Figure 28 shows that between the years 2007–2014, PHNSY and PNSY each employed nearly identical cost to run the apprenticeship program.

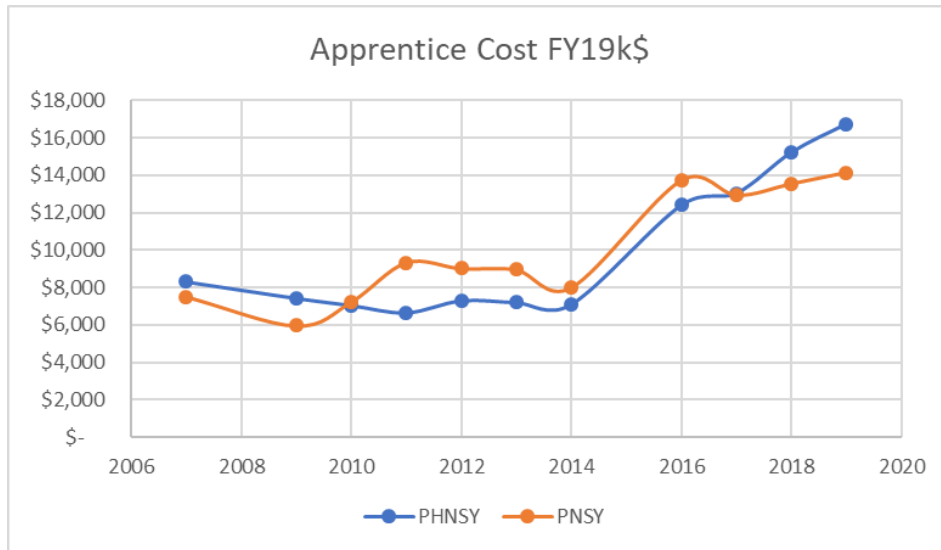


Figure 28. Total Apprenticeship Cost in FY19k\$. Source: FMB (2020).

Figure 29 shows the total apprenticeship cost per apprentice at both PHNSY and PNSY.

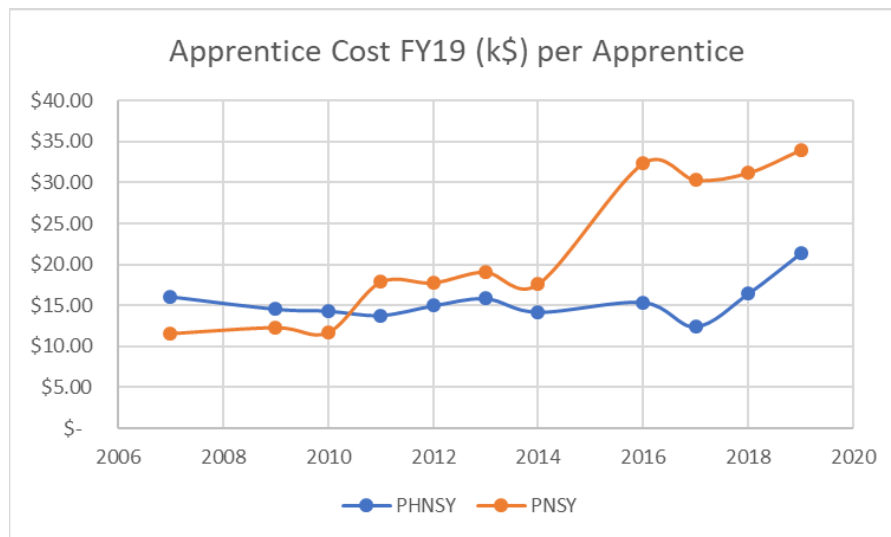


Figure 29. Total Apprenticeship Cost per Apprentice (FY19k\$/Apprentice). Source: FMB (2020).

In 2016, the total number of apprentices in PHNSY nearly doubled and has remained much higher, while PNSY apprentice count has remained relatively stagnant.

However, the apprenticeship overall costs displayed in Figure 28 shows that both shipyards have experienced significant growth in costs to train the apprentices. What is peculiar is the costs per apprentice as illustrated in Figure 29 shows that there is a significant disparity in the costs per apprentice that has manifested after 2014.

This disparity could indicate that either PNSY is not as efficient in training their apprentices, or that the true apprenticeship costs are being augmented or covered from different funding sources at the shipyards. Specifically, some of the apprenticeship costs at PHNSY could be paid for through project funds vice apprenticeship funds. If this was the case, this could explain the 80% increase in the difference of Direct Civilian Labor Costs per Man-Day at PHNSY and PNSY between FY2007-2014 and FY2016-2019 (Figure 22). Simply, the apprenticeship program at PHNSY could be not fully paying for the on-the-job training that apprenticeships receive. This timeline also directly corresponds to the conversation Carreras' had in 2014 regarding how apprentices are charged to projects. Because of the disparity between cost per apprentice at PHNSY and PNSY, it appears that this phenomenon could be happening at PHNSY, but not at PNSY.

F. EXTRAPOLATION ON THE COST PER APPRENTICE DISPARITY

To understand how the relationship between apprenticeship costs relates to labor cost per man-day, one must understand how pay is allocated to employees. In a simplistic example, ideally, an apprentice's paycheck is drawn from an "Apprentice Fund" and a qualified laborer's paycheck is drawn from either a "Shop Fund" when the laborer is not assigned to a project, or a "Project Fund" when the laborer is assigned to a project. The ratio of which fund the laborer's paycheck is drawn from depends on the hours worked on a project.

If an accounting system allows for an apprentice to receive their pay from a "Project Fund" account, then the expenditures from the "Apprentice Fund" would decrease, while the "Project Fund's" expenditures would increase to maintain the predetermined and fixed apprentice pay. This increase in expenditures from the "Project Fund" could be classified as "Direct Labor" and therefore increase the direct labor cost per man-day for the shipyard.

As can be seen in Figure 22, the average difference in direct labor cost per man-day at PHNSY and PNSY has increased by 80% between FY2007–FY2014 and FY2016–2019.

Because the expenditure from the Project Fund would presumptively require justification, some labor hours charged to a job are paid at an apprentice rate vice a qualified laborer’s rate, the change in expenditures for labor cost is likely immaterial per job. However, because the justification for labor hours for the apprentice is likely recorded as labor hours for a particular job along with the skilled laborer’s hours for the job, the total hours worked for the job has seemingly increased. Therefore, the next time that a project plans for that particular job, that job has grown in historical man-hours to complete.

To determine the effect that apprentice costs and time could have on a project, additional information regarding the apprenticeship program is required. PHNSY states on their NAVSEA website that in four years apprentices work a minimum of 7200 hours split between On-The-Job-Training (OJT), trade theory, and academic study. Apprentices also earn approximately \$20.03 per hour as a new apprentice. The following conservative assumptions are made to determine the effect of apprentice costs being absorbed by project funding.

1. Half of the total apprentices are improperly paid with project funds
2. One-Third of total apprentice hours are spent (OJT)
3. One-half of OJT time is improperly paid for by the project funds

With the above assumptions, at PHNSY, approximately 400 apprentices per year have some of their pay from project funds. Additionally, the approximate time spent OJT is 1200 hours in 4 years as an apprentice, therefore 300 hours in 1 year, which is 12.5 Man-Days. That means potentially 5000 Man-Days per year are attributed to project time vice apprentice time. This 5000 Man-Days is approximately 2.4 million dollars in just wages to the apprentices. These numbers will be compared to total costs and total man-hours per project.

Linear regression analysis was used to determine the average increase in project costs and man-days per year at PHNSY and PNSY. Additionally, the data was analyzed

prior to and after 2014 to show the change in project costs and man-days. Figures 30 and 31 below present the same data as Figures 11 and 12, however Figures 30 and 31 include trendlines to show the change in growth after 2014. Table 2 is a summary of the slopes for each regression as well as a slope for a trendline between 2007 and 2018.

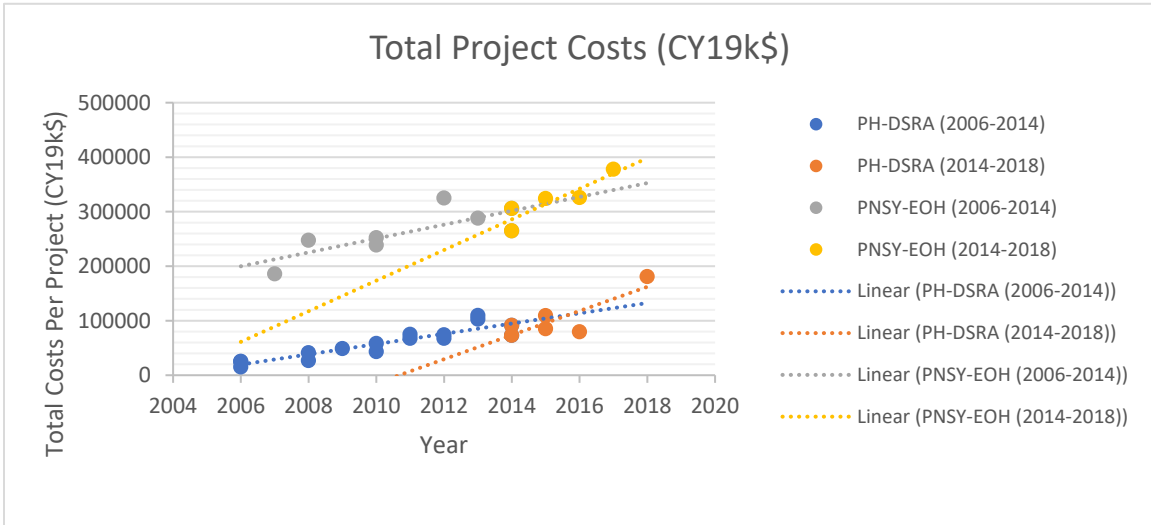


Figure 30. Total Project Costs with Trendlines, split in 2014

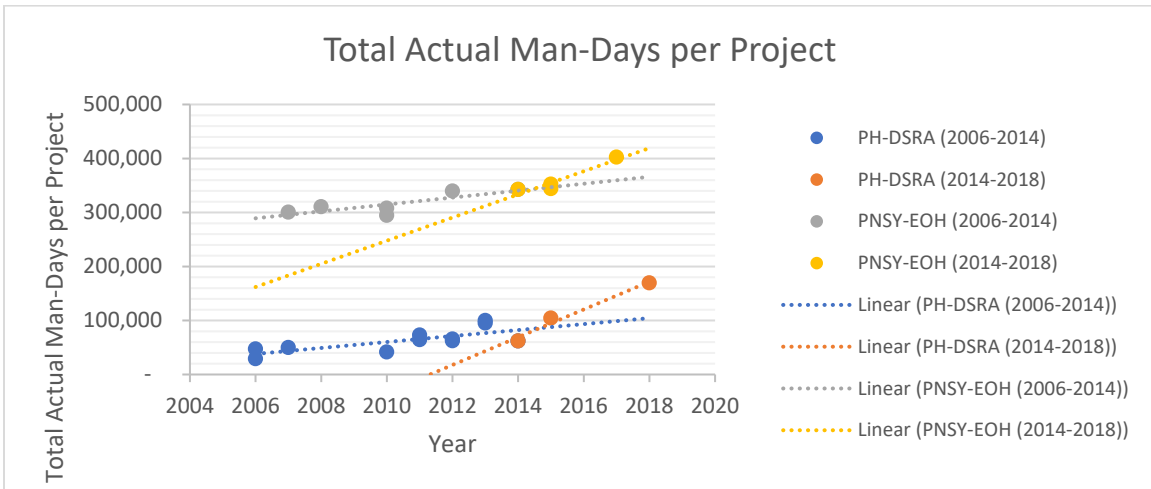


Figure 31. Total Man-Days per Project with Trendlines, split in 2014

Table 2. Summary of Regression Slopes

	Total Cost CY19k\$/FY (2007-2014)	Total Cost CY19k\$/FY (2014-2018)	Total Cost CY19k\$/FY (2007-2018)
PHNSY-DSRA	\$ 9,415.28	\$ 22,143.24	\$ 9,896.26
PNSY-EOH	\$ 12,722.70	\$ 28,090.32	\$ 14,569.23
	Man-Days/FY (2007-2014)	Man-Days/FY (2014-2018)	Man-Days/FY (2007-2018)
PHNSY-DSRA	5526.71	25688.85	8814.07
PNSY-EOH	6398.77	21430.79	8701.93

As can be seen from the regressions, DSRA's performed at PHNSY before 2014 could be expected to grow 9.415 million dollars per year, and 5526 man-days per year. After 2014, these growths were 22.143 million dollars per year, and 25688 man-days per year. The conservative estimation of the effect of project funds absorbing apprenticeship costs after 2014 was 19% ($2403/(22143.24-9415.28)$) of the change in costs per year, as well as 27% ($5500/(25688.85-5526.71)$) of the change in man-days per year. Furthermore, the apprenticeship burden could conservatively be 11% of the total change in costs per year for DSRA's and 21% of the change in man-days per year.

IV. CONCLUSION

A. SUMMARY

This thesis is meant to serve as an analysis of trends in growth of Los Angeles class submarine maintenance periods. To begin, this analysis evaluated the extent that shipyards perform maintenance on Los Angeles class submarines. This led to the observation that Pearl Harbor Naval Shipyard and Portsmouth Naval Shipyard perform significantly more DSRA, PIRA, and EOH maintenance periods on Los Angeles class submarines. Furthermore, a PHNSY appears to primarily perform the majority of Los Angeles class DSRAs while PNSY appears to primarily perform the majority of Los Angeles class EOHs. The large history of DSRA and EOH maintenance at PHNSY and PNSY allows for trend analysis of those maintenance periods at those two specific shipyards, to attempt to identify underlying tendencies.

After identifying PHNSY and PNSY as the two shipyards that perform the majority of specific maintenance availabilities on Los Angeles class submarines, a similar trend appeared for the growth at the two shipyards. Both DSRAs at PHNSY and EOHs at PNSY had grown on average roughly 8800 Man-Days every year since 2007. However, when trends in apprenticeship costs were compared, in 2014 PNSY had an unexpected and dramatic increase in the apprenticeship costs per apprentice when compared to PHNSY. A theory was proposed that the cost of an apprentice is lower at PHNSY because PHNSY is inappropriately paying for apprenticeship time with maintenance project funds. Although these funds can be significantly less than the total cost of the maintenance availability, the man-hours associated with wages to the apprentices could be inappropriately charged to specific jobs, which then leads to either longer time in the maintenance period, or an inability to accurately predict when the submarine will exit the shipyard and become operational.

After the identification of the apprenticeship cost deviation in 2014, a trend analysis was performed on the cost and man-days associated with DSRAs and EOHs at PHNSY and PNSY before 2014 and after 2014. This found that there was a significant increase in

both cost and man-days of DSRAs and EOHs at their respective shipyards. While both PHNSY and PNSY increased their costs and man-days, PHNSY did so at a faster rate than PNSY. This shift in cost and man-days occurred at approximately the same time as Carreras' interview with shipyard leadership in which discussions on how apprentice OJT would be charged. Although the Carreras' interview is a single data point, the trending in apprentice costs at PHNSY indicate a possible connection.

Although this theory of misappropriated apprenticeship costs is feasible, much more data is required before a conclusion could be reached. Additionally, the apparent correlation in apprenticeship costs and DSRA/EOH growth does not mean that there is definitely a causality between the two. However, what this analysis has hopefully brought to light is the real consequences that could arise from misappropriated work hours. A need has risen for accountable and objective tracking of job hours.

B. RECOMMENDATION

It is recommended that PHNSY, as well as all public shipyards, implement an electronic tracking mechanism for hours worked on each job. It is recommended that this tracking mechanism should have the capability of accurately tracking the total number of hours worked by both apprentices and those that have completed the apprenticeship program. This will contribute to accurate determinations of labor requirements to complete specific jobs, and a more accurate prediction of submarine maintenance duration. It is important to note that the purpose of this tracking is not for altering the wages of individual personnel, but rather for an accurate tracking mechanism to predict future work. The tracking mechanism should include a mechanism to ensure anonymity of the workers for the purpose of hour tracking. This thesis makes no claims to the adequacy or accountability for proper work control or quality assurance tracking mechanisms already in place.

C. FURTHER STUDIES

Further studies on this topic could include an analysis on current tracking of apprenticeship costs and job hours. These analyses should focus on the process for recording hours worked and how those recorded hours are utilized for both wage/benefits

as well as engineering data points. These analyses would be benefited from additional fidelity that the recommended modernization of job tracking could bring.

Additionally, further studies could also include the following:

1. Relative competition between shipyards, as it is possible that the shipyards have begun to monopolize different availability types.
2. Labor growth rates compared to availability growth in complexity and time, as it is possible that the labor growth rates could be driving the length of shipyard maintenance.
3. The effect of skilled labor work force retirements rates has on the duration of availabilities, as it is possible that the skilled labor work force is retiring faster than being replaced by new skilled workers.

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APPENDIX A. LABOR MAN-DAYS

The table below shows direct labor man-days for all Los Angeles Class submarine maintenance performed at public shipyards started and completed between FY2005 and FY2019. This data is consolidated Department of the Navy Budget Estimates Justification Estimates provided by FMB.

Shipyards	Hull #	FY	Avail Type	Budget Mission Direct Labor Man-Days	Budget Reimb Labor Man-Days	Actual Mission Direct Labor Man-Days	Actual Reimb Labor Man-Days	Total Budget Direct Labor Man-Days	Total Actual Direct Labor Man-Days
NNSY	714	2009	DSRA	21,816	403	47,818	645	22,219	48,463
NNSY	764	2009	DSRA	37,318	7,769	57,544	14,343	45,087	71,887
NNSY	750	2010	DSRA	31,811	175	18,859	284	31,986	19,143
NNSY	765	2010	DSRA	40,517	17,318	52,012	15,716	57,835	67,728
NNSY	750	2012	EOH	233,711	20,322	322,559	20,202	254,033	342,761
NNSY	753	2013	EOH	239,698	21,902	555,429	34,749	261,600	590,178
PHNSY	688	2005	PIRA	75,864	-	104,602	-	75,864	104,602
PHNSY	705	2006	DSRA	29,180	1,580	28,886	131	30,760	29,017
PHNSY	752	2006	DSRA	29,180	6,579	44,180	2,944	35,759	47,124
PHNSY	713	2007	DSRA	27,269	4,267	48,162	1,801	31,536	49,963
PHNSY	701	2009	PIRA	34,335	3,346	116,079	232	37,681	116,311
PHNSY	721	2009	EOH	245,186	19,072	257,374	16,139	264,258	273,513
PHNSY	698	2010	DSRA	31,157	1,770	40,955	631	32,927	41,586
PHNSY	722	2010	EOH	259,971	35,930	241,250	18,314	295,901	259,564
PHNSY	699	2011	DSRA	41,233	609	72,837	53	41,842	72,890

Shipyard	Hull #	FY	Avail Type	Budget Mission Direct Labor Man-Days	Budget Reimb Labor Man-Days	Actual Mission Direct Labor Man-Days	Actual Reimb Labor Man-Days	Total Budget Direct Labor Man-Days	Total Actual Direct Labor Man-Days
PHNSY	705	2011	PIRA	95,116	66	123,706	7	95,182	123,713
PHNSY	766	2011	DSRA	34,930	4,678	60,900	3,549	39,608	64,449
PHNSY	713	2012	PIRA	50,015	112	62,720	26	50,127	62,746
PHNSY	763	2012	DSRA	37,951	1,711	59,315	3,054	39,662	62,369
PHNSY	771	2012	DSRA	27,983	1,055	62,751	2,667	29,038	65,418
PHNSY	715	2013	PIRA	74,458	330	145,453	371	74,788	145,824
PHNSY	724	2013	DSRA	50,604	1,272	98,402	1,476	51,876	99,878
PHNSY	773	2013	DSRA	50,532	739	93,589	1,479	51,271	95,068
PHNSY	758	2014	EOH	267,131	18278	368,465	33893	285,409	402,358
PHNSY	770	2014	DSRA	50,613	2,609	58,296	3,546	53,222	61,842
PHNSY	717	2015	DSRA	76,228	895	104,155	234	77,123	104,389
PHNSY	759	2015	EOH	265,175	12495	397,285	9664	277,670	406,949
PHNSY	721	2018	DSRA	176,591	2016	168,527	887	178,607	169,414
PNSY	724	2007	EOH	255,227	40,155	260,753	39,784	295,382	300,537
PNSY	723	2008	EOH	273,546	28,464	281,321	29,292	302,010	310,613
PNSY	760	2008	DSRA	39,906	4,515	38,868	3,018	44,421	41,886
PNSY	767	2009	DSRA	35,047	4,415	41,845	5,598	39,462	47,443
PNSY	725	2010	EOH	216,019	22,677	269,832	24,761	238,696	294,593
PNSY	751	2010	EOH	246,156	26,486	273,044	34,734	272,642	307,778
PNSY	711	2011	PIRA	55,000	453	53,691	3,067	55,453	56,758
PNSY	720	2012	PIRA	55,000	6,037	94,932	1,222	61,037	96,154
PNSY	752	2012	EOH	223,802	23,927	314,550	25,000	247,729	339,550

Shipyard	Hull #	FY	Avail Type	Budget Mission Direct Labor Man-Days	Budget Reimb Labor Man-Days	Actual Mission Direct Labor Man-Days	Actual Reimb Labor Man-Days	Total Budget Direct Labor Man-Days	Total Actual Direct Labor Man-Days
PNSY	706	2013	PIRA	52,500	51	67,070	-	52,551	67,070
PNSY	756	2014	EOH	231,855	17519	326,035	16402	249,374	342,437
PNSY	760	2015	EOH	258,640	17569	321,656	30671	276,209	352,327
PNSY	767	2015	EOH	273,252	2370	323,904	20149	275,622	344,053
PNSY	719	2016	PIRA	135,815	97	204,443	468	135,912	204,911
PNSY	723	2016	DSRA	63,455	738	-	67,413	64,193	67,413
PNSY	761	2017	EOH	214,054	22942	371,636	30614	236,996	402,250
PNSY	722	2018	DSRA	-	98,160	-	121,622	98,160	121,622
PNSY	751	2019	DSRA	67,757	19758	106,274	677	87,515	106,951
PSNSY	725	2006	DSRA	19,640	1,067	35,359	130	20,707	35,489
PSNSY	754	2006	DSRA	19,312	4,610	32,437	1,581	23,922	34,018
PSNSY	759	2008	DSRA	31,797	6,059	37,143	2,596	37,856	39,739

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APPENDIX B. AVAILABILITY TOTAL COST

The following data is the cost in CY2019\$ of all availabilities completed between FY2007 and FY2019. The data is provided by VAMOSC but has been consolidated. Similar to the CBO 2019 report, there are multiple incidents where data provided by VAMOSC was inconsistent with other data available or a maintenance a submarine incurred costs at multiple shipyards for the same maintenance availability. In this situation, the total cost was allocated to the shipyard that performed the majority of the work. Additionally, some availabilities were not included due to extenuating circumstances. For example, neither the USS *San Francisco* was not included for DSRA analysis the year after her collision nor was the USS *Miami*'s final EOH.

CNO Start Date	CNO Completion Date	Availability Type Description	FY	CY\$2019 Total Costs	Hull #	Specific Shipyard
6/1/2007	8/31/2007	DOCKING SELECTED RESTRICTED AVAILABILITY	2007	\$ 33,475,834.18	758	PSNSY
5/11/2007	9/28/2007	DOCKING SELECTED RESTRICTED AVAILABILITY	2007	\$ 11,141,793.96	757	EB
10/4/2007	12/14/2007	DOCKING SELECTED RESTRICTED AVAILABILITY	2008	\$ 19,723,321.63	706	PNSY
9/30/2007	3/11/2008	DOCKING SELECTED RESTRICTED AVAILABILITY	2007	\$ 42,738,657.30	756	NNSY

CNO Start Date	CNO Completion Date	Availability Type Description	FY	CY\$2019 Total Costs	Hull #	Specific Shipyard
8/1/2007	5/1/2008	PRE-INACTIVATION RESTRICTED AVAILABILITY	2007	\$ 64,038,149.39	691	PNSY
1/14/2008	6/16/2008	DOCKING SELECTED RESTRICTED AVAILABILITY	2008	\$ 26,667,504.62	722	PHNSY
6/24/2008	11/15/2008	DOCKING SELECTED RESTRICTED AVAILABILITY	2008	\$ 44,005,115.31	760	PNSY
9/1/2008	12/20/2008	DOCKING SELECTED RESTRICTED AVAILABILITY	2008	\$ 40,913,781.70	759	PHNSY
8/18/2008	1/10/2009	DOCKING SELECTED RESTRICTED AVAILABILITY	2008	\$ 41,056,312.87	713	PHNSY
3/24/2007	1/25/2009	ENGINEERED OVERHAUL	2007	\$ 185,896,059.96	724	PNSY
10/6/2008	3/15/2009	DOCKING SELECTED RESTRICTED AVAILABILITY	2009	\$ 45,550,159.96	714	NNSY
3/15/2009	7/29/2009	DOCKING SELECTED RESTRICTED AVAILABILITY	2009	\$ 48,648,284.66	715	PHNSY
4/1/2009	8/31/2009	DOCKING SELECTED RESTRICTED AVAILABILITY	2009	\$ 70,822,682.41	764	NNSY
3/16/2009	9/18/2009	DOCKING SELECTED RESTRICTED AVAILABILITY	2009	\$ 34,828,925.84	719	EB

CNO Start Date	CNO Completion Date	Availability Type Description	FY	CY\$2019 Total Costs	Hull #	Specific Shipyard
2/17/2009	12/18/2009	PRE-INACTIVATION RESTRICTED AVAILABILITY	2009	\$ 126,727,283.75	701	PHNSY
8/1/2009	12/24/2009	DOCKING SELECTED RESTRICTED AVAILABILITY	2009	\$ 46,765,839.86	767	PNSY
1/5/2009	2/7/2010	PRE-INACTIVATION RESTRICTED AVAILABILITY	2009	\$ 144,508,725.16	700	PNSY
11/7/2009	3/9/2010	DOCKING SELECTED RESTRICTED AVAILABILITY	2010	\$ 43,011,027.96	698	PHNSY
2/5/2010	7/27/2010	DOCKING SELECTED RESTRICTED AVAILABILITY	2010	\$ 56,072,147.61	765	NNSY
9/30/2008	11/23/2010	ENGINEERED OVERHAUL	2008	\$ 247,440,104.57	723	PNSY
8/21/2010	3/5/2011	DOCKING SELECTED RESTRICTED AVAILABILITY	2010	\$ 58,064,960.74	762	PHNSY
10/1/2009	6/2/2011	ENGINEERED OVERHAUL	2010	\$ 238,579,273.56	725	PNSY
10/1/2009	11/10/2011	ENGINEERED OVERHAUL	2010	\$ 294,845,761.74	721	PHNSY
2/28/2011	12/2/2011	DOCKING SELECTED RESTRICTED AVAILABILITY	2011	\$ 74,767,618.92	699	PHNSY
6/30/2011	12/17/2011	PRE-INACTIVATION RESTRICTED AVAILABILITY	2011	\$ 74,209,606.70	711	PNSY

CNO Start Date	CNO Completion Date	Availability Type Description	FY	CY\$2019 Total Costs	Hull #	Specific Shipyard
9/6/2011	3/11/2012	DOCKING SELECTED RESTRICTED AVAILABILITY	2011	\$ 67,560,883.38	766	PHNSY
5/29/2010	4/1/2012	ENGINEERED OVERHAUL	2010	\$ 252,187,186.87	751	PNSY
6/16/2011	6/15/2012	PRE-INACTIVATION RESTRICTED AVAILABILITY	2011	\$ 127,862,175.12	705	PHNSY
7/29/2010	7/29/2012	ENGINEERED OVERHAUL	2010	\$ 274,750,758.60	722	PHNSY
2/7/2012	8/5/2012	DOCKING SELECTED RESTRICTED AVAILABILITY	2012	\$ 67,421,790.82	763	PHNSY
2/8/2012	8/24/2012	PRE-INACTIVATION RESTRICTED AVAILABILITY	2012	\$ 68,417,717.84	713	PHNSY
7/10/2012	2/26/2013	DOCKING SELECTED RESTRICTED AVAILABILITY	2012	\$ 74,020,324.63	771	PHNSY
11/6/2012	5/28/2013	DOCKING SELECTED RESTRICTED AVAILABILITY	2013	\$ 109,318,595.79	724	PHNSY
9/5/2012	8/2/2013	PRE-INACTIVATION RESTRICTED AVAILABILITY	2012	\$ 118,284,937.94	720	PNSY
11/1/2011	8/30/2013	ENGINEERED OVERHAUL	2012	\$ 325,027,797.07	752	PNSY
1/4/2012	2/28/2014	ENGINEERED OVERHAUL	2012	\$ 367,838,150.37	750	NNSY
8/19/2013	4/16/2014	DOCKING SELECTED RESTRICTED AVAILABILITY	2013	\$ 102,731,828.86	773	PHNSY

CNO Start Date	CNO Completion Date	Availability Type Description	FY	CY\$2019 Total Costs	Hull #	Specific Shipyard
10/17/2013	4/27/2014	PRE-INACTIVIATION RESTRICTED AVAILABILITY	2014	\$ 79,956,506.48	706	PNSY
3/4/2013	7/3/2014	PRE-INACTIVIATION RESTRICTED AVAILABILITY	2013	\$ 159,155,261.93	715	PHNSY
1/29/2013	12/17/2014	ENGINEERED OVERHAUL	2013	\$ 287,962,412.45	754	PNSY
5/6/2014	12/24/2014	DOCKING SELECTED RESTRICTED AVAILABILITY	2014	\$ 73,162,652.96	770	PHNSY
1/28/2014	1/18/2015	DOCKING SELECTED RESTRICTED AVAILABILITY	2014	\$ 91,139,144.98	698	PHNSY
10/21/2014	5/5/2015	DOCKING SELECTED RESTRICTED AVAILABILITY	2015	\$ 85,227,618.53	772	PHNSY
12/10/2014	6/5/2015	PRE-INACTIVIATION RESTRICTED AVAILABILITY	2015	\$ 51,544,806.42	700	PNSY
12/4/2013	8/7/2015	ENGINEERED OVERHAUL	2014	\$ 264,824,787.62	757	PNSY
2/11/2014	2/12/2016	ENGINEERED OVERHAUL	2014	\$ 411,571,315.05	758	PHNSY
4/28/2015	5/21/2016	DOCKING SELECTED RESTRICTED AVAILABILITY	2015	\$ 109,258,049.80	717	PHNSY
8/26/2014	8/13/2016	ENGINEERED OVERHAUL	2014	\$ 305,792,969.38	756	PNSY
5/5/2016	11/1/2016	DOCKING SELECTED RESTRICTED AVAILABILITY	2016	\$ 79,587,304.25	723	PHNSY

CNO Start Date	CNO Completion Date	Availability Type Description	FY	CY\$2019 Total Costs	Hull #	Specific Shipyard
1/8/2016	4/30/2017	PRE-INACTIVATION RESTRICTED AVAILABILITY	2016	\$ 190,657,124.01	719	PNSY
6/12/2015	5/13/2017	ENGINEERED OVERHAUL	2015	\$ 324,019,382.74	760	PNSY
6/8/2016	5/1/2018	ENGINEERED OVERHAUL	2016	\$ 325,821,471.76	767	PNSY
1/6/2014	8/15/2018	ENGINEERED OVERHAUL	2014	\$ 570,411,027.22	753	NNSY
8/25/2015	8/28/2018	ENGINEERED OVERHAUL	2015	\$ 427,584,383.09	759	PHNSY
3/13/2018	2/6/2019	DOCKING SELECTED RESTRICTED AVAILABILITY	2018	\$ 151,221,624.22	722	NNSY
10/18/2017	4/6/2019	DOCKING SELECTED RESTRICTED AVAILABILITY	2018	\$ 113,081,746.72	725	HII
11/8/2017	4/24/2019	DOCKING SELECTED RESTRICTED AVAILABILITY	2018	\$ 180,673,566.40	721	PHNSY
1/13/2017	7/22/2019	ENGINEERED OVERHAUL	2017	\$ 377,723,438.56	761	PNSY
2/21/2019	8/20/2019	DOCKING SELECTED RESTRICTED AVAILABILITY	2019	\$ 113,357,925.77	751	PHNSY

APPENDIX C. FINANCIAL DATA

The following table is a compilation of select financial information of Pearl Harbor Naval Shipyard and Portsmouth Naval Shipyard. This financial information was deemed directly related to submarine maintenance at the two predominantly submarine only public shipyards. This data is consolidated Department of the Navy Budget Estimates Justification Estimates provided by FMB.

	Year	2007	2009	2010	2011	2012	2013	2014	2016	2017	2018	2019
Direct O&M Fleet Base (FY19k \$)	PHNS Y	\$394,00 5.35	\$485,90 2.75	\$584,69 8.04	\$652,47 8.29	\$651,66 2.62	\$604,16 6.32	\$682,44 2.41	\$739,32 0.85	\$784,08 3.35	\$841,83 6.62	\$964,20 3.00
	PNSY	\$177,42 4.21	\$396,72 5.93	\$426,37 8.30	\$483,25 0.98	\$483,43 3.53	\$510,27 1.14	\$498,32 6.22	\$496,90 9.25	\$646,87 9.50	\$721,35 0.80	\$875,69 9.00
Unit Cost (FY19\$ per Manday)	PHNS Y	\$769.62	\$786.70	\$869.24	\$916.20	\$804.66	\$861.61	\$922.50	\$910.64	\$980.19	\$984.67	\$1,060.66
	PNSY	\$543.97	\$614.97	\$753.58	\$733.15	\$810.87	\$808.66	\$797.96	\$770.23	\$864.51	\$793.39	\$996.64
Direct Civilian Labor (FY19k \$)	PHNS Y	\$178,93 3.25	\$230,75 3.67	\$235,21 3.56	\$265,75 3.36	\$282,74 1.18	\$269,94 6.21	\$290,28 1.62	\$317,08 7.03	\$345,14 0.93	\$360,05 5.94	\$412,87 6.00
	PNSY	\$196,59 4.32	\$232,15 1.99	\$239,87 7.73	\$263,56 9.82	\$260,31 5.13	\$310,96 8.62	\$270,43 3.35	\$313,75 6.28	\$342,34 3.64	\$369,79 2.93	\$388,62 0.00
Direct Material	PHNS Y	\$36,828 .98	\$40,661 .35	\$56,572 .27	\$63,475 .02	\$66,393 .05	\$67,850 .09	\$81,092 .14	\$74,584 .90	\$96,296 .96	\$144,69 8.53	\$108,48 7.00
	PNSY	\$33,609 .03	\$36,845 .23	\$43,358 .10	\$60,437 .62	\$75,125 .45	\$74,021 .39	\$69,475 .10	\$93,136 .88	\$108,56 5.52	\$130,92 8.03	\$166,09 2.00

	Year	2007	2009	2010	2011	2012	2013	2014	2016	2017	2018	2019
(FY19k \$)												
Overhead Civilian Labor (FY19k \$)	PHNS Y	\$142,686.41	\$148,617.75	\$173,062.62	\$171,064.88	\$173,175.06	\$172,771.55	\$166,444.76	\$215,213.93	\$231,173.98	\$260,189.40	\$271,666.00
	PNSY	\$97,030.25	\$124,986.08	\$142,536.97	\$140,873.08	\$153,512.15	\$104,788.18	\$165,810.01	\$203,566.71	\$217,412.77	\$238,602.55	\$279,312.00
Overhead Non-Labor (FY19k \$)	PHNS Y	\$45,156.38	\$36,348.40	\$54,348.43	\$62,624.93	\$45,859.04	\$52,859.96	\$81,603.16	\$65,321.77	\$90,983.16	\$101,786.06	\$97,614.00
	PNSY	\$37,494.21	\$35,818.46	\$43,143.82	\$52,826.03	\$43,738.77	\$63,289.81	\$67,230.21	\$69,245.74	\$64,408.90	\$95,102.06	\$69,255.00
Mission Man-Days Submarines	PHNS Y	145,332.00	313,190.00	280,370.00	360,127.00	427,829.00	376,587.00	401,205.00	383,251.00	371,118.00	426,563.00	505,240.00
	PNSY	166,672.00	437,251.00	424,344.00	437,462.00	442,044.00	469,070.00	399,999.00	497,629.00	596,548.00	535,456.00	587,554.00
Civilian End Strength	PHNS Y	4030	4279	4396	4405	4525	4334	4457	5050	5250	5549	5832
	PNSY	3901	4189	4466	4539	4672	4614	4749	5508	5587	6023	6262

APPENDIX D. APPRENTICESHIP DATA

The table below shows selected apprentice and apprenticeship costs associated with all four public shipyards that perform submarine maintenance. This data is consolidated Department of the Navy Budget Estimates Justification Estimates provided by FMB.

	FY Year	2007	2009	2010	2011	2012	2013	2014	2016	2017	2018	2019
Total Apprentices	PHNS Y	516	509	491	482	487	454	500	806	1050	927	785
	PNSY	646	482	616	522	506	468	454	424	426	434	416
	NNSY	536	425	399	712	741	813	847	916	988	1050	1185
	PSNS Y	743	746	793	773	807	775	896	995	1039	1017	992
Apprentice Cost FY19 (k\$)	PHNS Y	\$8,297	\$7,420	\$7,038	\$6,652	\$7,292	\$7,195	\$7,101	\$12,406	\$13,040	\$15,225	\$16,747
	PNSY	\$7,507	\$5,953	\$7,236	\$9,334	\$9,011	\$8,951	\$8,003	\$13,730	\$12,928	\$13,548	\$14,146
	NNSY	\$10,823	\$6,867	\$9,104	\$11,380	\$13,933	\$11,449	\$13,210	\$18,031	\$17,118	\$18,299	\$15,567
	PSNS Y	\$11,063	\$10,779	\$10,848	\$10,686	\$11,122	\$11,449	\$12,970	\$19,128	\$19,801	\$12,818	\$13,900

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LIST OF REFERENCES

- Carreras, M. (2019, April 12). Trust. [Memorandum] Pearl Harbor, HI: NAVSEA. This document is For Official Use Only.
- Chief of Naval Operations. (2013, January 22). *Submarine engineered operating cycle program*. (OPNAVINST 3120.33C). Washington, DC: Author.
- COMNAVSEASYSCOM (2010, December 27). Technical foundation for the USS Los Angeles class docking selected restricted availability TYCOM Notionals [Letter 4700 Ser SEA 07/1332 to CNO]. Provided electronically by SUBPAC N4.
- Congressional Budget Office. (2019, April). Costs of Submarine Maintenance at Public and Private Shipyards. Washington, DC: Government Printing Office. Retrieved from <https://www.cbo.gov/publication/55032>
- Government Accountability Office. (2019). Navy Maintenance: Persistent and Substantial Ship and Submarine Maintenance Delays Hinder Efforts to Rebuild Readiness. (GAO Publication No. 20–257). Washington, DC: U.S. Government Printing Office
- Lindle, M., & Wisz, R. (2019). Increasing cost and duration at PHNSY [Master's thesis, Naval Postgraduate School]. NPS Archive: Calhoun. <https://calhoun.nps.edu/handle/10945/65074>

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