NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

IMPROVING UTILIZATION OF SAILORS WITH CRITICAL SKILLS IN UNDERMANNED RATINGS

by

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June 2020

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REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** June2020	**3. REPORT TYPE AND DATES COVERED** Master's thesis

4. TITLE AND SUBTITLE
IMPROVING UTILIZATION OF SAILORS WITH CRITICAL SKILLS IN UNDERMANNED RATINGS

5. FUNDING NUMBERS

6. AUTHOR(S) April J. Robertson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT (maximum 200 words)

This thesis proposes and analyzes the effects of a new method of distributing Sailors with critical skills among undermanned ratings. It focuses on the distribution of Operations Specialists (OSs) on DDG 51 Flt I destroyers. OSs are known for being underutilized when in port and working longer hours than expected while deployed. The improved utilization of Sailors will result in a career path that supports work-life balance and eases the burden on recruiters to meet accession quotas.

The analysis uses a discrete event simulation model to determine the effects of a surge command option on manning. Sailors with in-demand skills can choose assignment to the surge command rather than assignment to a specific ship. To facilitate manning at the surge command, fewer billets are authorized on ships while they are not deployed. When a ship deploys, it draws Sailors from the surge command to supplement manning. Surge command tours are 24 months while regular sea tours are five years. The compressed tour minimizes underutilized man-hours on in-port ships while improving manning on deployed ships.

We conclude that a surge command provides increased deployment manning and decreased in-port manning, resulting in up to 315 fewer Sailors being under-utilized at any given time. Improved workload balance may result in increased retention. We recommend further studies to expand the scope of the model as well as studies to determine the effects of a surge command on Sailor retention.

14. SUBJECT TERMS
manning, surge command, quality of life, Operations Specialists, OS

15. NUMBER OF PAGES
67

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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IMPROVING UTILIZATION OF SAILORS WITH CRITICAL SKILLS IN UNDERMANNED RATINGS

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
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List of Acronyms and Abbreviations

COB current onboard

CNO Chief of Naval Operations

CNP Chief of Naval Personnel

DES discrete event simulation

GAO Government Accountability Office

MOE measures of effectiveness

NAVMAC Navy Manpower Analysis Center

NEC Navy enlisted classification

NPC Navy Personnel Command

OFRP Optimized Fleet Response Plan

OS Operations Specialist

OSC OS chief

OSSN OS seaman

PAQ present at quarters

POC proof of concept

SDIP Sea Duty Incentive Pay

VCNO Vice Chief of Naval Operations

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Executive Summary

This thesis develops a proof of concept (POC) model for critical skilled sailor distribution in undermanned sea duty ratings. Specifically, this thesis proposes and models a new system of personnel assignment known as a surge command. A surge command is designed to address workload imbalances in ratings that have little rating specific occupational work requirements while in port but are undermanned and overworked while deployed. The POC focuses on the Operations Specialists (OS) rating and models deployment cycles and OS manning for DDG 51 Flt I destroyers.

Over the past century, anecdotal observations have indicated that overworked sailors and airman fatigue can manifest itself as safety mishaps and deteriorated work quality. More recently, research into work underload has emerged demonstrating that underload can be just as detrimental as work overload. Recent Naval Postgraduate School theses have documented Sailor workload and under-manning issues across the fleet. The effects of these documented issues, when coupled with a rating that is known to have little rating-specific work while in port and grueling work hours while underway, can significantly impact retention, which further burdens manning issues. OSs are an example of a rating affected by this workload imbalance. This thesis proposes a model that increases underway manning while reducing manning during periods of in-port under-utilization for OS Sailors.

When the proposed surge command is utilized, in-port ship manning requirements are reduced, and the billets are shifted back to the surge command. When a ship deploys, it draws Sailors from the surge command to supplement manning shortfalls during deployment. When the deployment ends, the surge Sailors return to the surge command and await another deployment. During a regular sea tour, a Sailor is assigned to a single ship for four or five years. During that time, the ship will normally deploy twice, accounting for about 12–18 months of underway time. However, in some cases, the timing works out such that a Sailor may do only one deployment while assigned a sea tour. The remainder of the tour, the ship is mostly in-port and OS Sailors are under-utilized. During assignment to a surge command, a Sailor's sea tour is proposed to be two years. During this time, the Sailor will deploy twice, each time with a different ship as required. The Sailor will spend the same 12–18 months deployed that they would on a typical regular sea tour, but they will skip the

long periods of less than optimal occupational utilization. After their assignment to a surge command, Sailors will continue the normal sea-shore rotation with assignment to a shore command.

The fleet manning model proposed in this research is a discrete event simulation model created using the DESpy package in Python. It models destroyers as they rotate between maintenance periods in which they are not available to deploy, and periods of availability for deployment and deployment. The ships are modeled to be manned with OS Sailors according the DDG 51 Flt I ship manpower documents. Sailors in the model progress through their careers by advancing in rank and moving between sea and shore duty assignments. The model allows for Sailors to be assigned to a surge command when input parameters include surge utilization data but assigns Sailors to a regular sea tour when the input data indicates no surge utilization. Multiple replications are run at various surge utilization levels (between zero and one hundred percent). Deployment manning levels are tracked to compare results at each surge utilization level.

Our results indicate that the use of a surge command slightly improves deployment manning levels. However, it has a significant impact on in-port manning levels. There are as many as 315 fewer Sailors assigned to non-deployed ships at a time, thereby decreasing under-utilized man-hours. The little available occupational work on those ships can then be distributed among fewer assigned Sailors, improving the under-utilization rate for the assigned Sailors. As a POC, the results of this research are promising and warrant further studies to investigate the idea of a surge command. Further work should include reducing model simplifications and assumptions to create a more detailed Sailor and ship models as well as use of the optimization model in Appendix B. It should also include Sailor interviews to gauge the interest in the surge concept and appropriate policy requirements to maximize the utility of a surge command assignment process.

Acknowledgments

I would like to thank my advisors for all of their support throughout this process. Dr. Buss, thank you for your advice and infinite patience as I built the model. Dr. Craparo, thank you for your help in refining my idea into something that could be modeled and for all your working in getting a usable optimization, even if we never used it! The moral support you provided over the past months was invaluable and helped me get through this process and put together a thesis that I am proud to have done. CDR Hatch, thank you for believing in my idea and providing great feedback and editing that certainly prevented some embarrassing mistakes! Without the support of you all, I would not have even known where to begin; thank you for all the time you put into this thesis with me.

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CHAPTER 1: Introduction

The Chief of Naval Operations (CNO) has named Navy Sailors as one of his top priorities. During his swearing-in speech, he talked of "taking care of our most important weapon system: our Sailors and their families" (*AirForce Magazine* 2019, p. 1). Caring for Sailors can include focusing on job fulfillment and satisfaction as well as on quality of life. As a Junior Officer onboard an operational ship working directly with enlisted Sailors, it is easy to identify areas for improvement. While deployed, many Sailors lack adequate sleep and work over 81 hours a week (Fletcher 2018). Though the hours can be long, a Sailor can expect to do one to two full six-month deployments during each sea tour assignment, based on the current Optimized Fleet Response Plan (OFRP) (Chief of Naval Operations [CNO] 2014b). However, in some cases, the timing works out such that a Sailor may do only one deployment during a sea tour. This is due to the mismatch between the 36-month OFRP timeline and the 48- to 60-month sea tour assignment timeline.

Sailors spend the majority of their sea tours in port. While in port, the workload can vary depending on the Sailor's rate (skill set) and rating (skill set and pay grade combination) and the ship's readiness phase. Of particular interest are rates, or occupational skills, for which the in-port workload is significantly different from the workload during deployments. The mismatch in workload between the two periods can cause burnout during deployments followed by boredom while in port (Hebb 1955; Game 2007). Both conditions can have a negative impact on job fulfillment and, subsequently, retention. One rate that is especially susceptible to this imbalance is Operations Specialist (OS). The occupational skills associated with the OS rating, such as contact identification and management, are directly related to being underway. The requirement for OS-required skills is minimized while in port, and the equipment OSs use while underway is maintained by other rates. This leads to a minimal amount of in-rate work for OS Sailors during in-port periods. Often, they are kept busy in cleaning their spaces, polishing ornamental brass around the ship, and assisting other divisions in their cleaning and ship-preservation responsibilities. Such activities are important in the upkeep of a ship, but they are not the essential skills that Sailors expect to perform when they enlist in the Navy. Furthermore, the occupational skills for a rate are necessary to maintain, not just for proficiency, but for promotional purposes as well. When a Sailor works outside of their skill area for an extended period leading into an advancement exam, they are undoubtedly at a disadvantage compared to Sailors who are practicing the skill daily. The combination of a lack of meaningful rate-specific work while in port and diminished advancement opportunities may contribute to dissatisfaction, and reenlist decisions.

Diminished retention can lead to fewer Sailors to fill billets on ships, so when a ship is deployed, there are not enough OS Sailors to perform the required duties within the Navy workweek as prescribed by the Vice Chief of Naval Operations (1967). The result often observed across the fleet is for OS Sailors to maintain a "port and starboard" watch rotation for the duration of a deployment. This rotation involves 6 hours on watch, and 6 hours off watch. The off-watch hours include other divisional duties such as training and space preservation, as well as ship-wide training such as general quarters and man-overboard drills. Such a schedule can make it difficult to get adequate sleep and to maintain focus throughout the entire watch. With too little rate-specific work while in port and too much while deployed, OS is a prime rating to examine for improvements in line with the CNO's desire to care for our Sailors.

1.1 Scope

This thesis proposes a new methodology for distributing OS Sailors assigned to sea duty, with the aim of improving deployment manning, and workload, while minimizing the under-utilized hours of OS Sailors assigned to ships not deployed. This thesis demonstrates a model intended to act as a proof of concept (POC) for the method of distribution, referred to herein as a Surge command.

The model simplifies the fleet and the Sailors to the extent practicable for a POC and it only examines the destroyer fleet and OS Sailors. If the POC is successful, the model can be expanded to include other ship types and other rates, as appropriate. As a POC, this thesis does not propose to show what the fleet manning will look like under the Surge command distribution method. Rather, it demonstrates that utilizing the surge command can improve deployment manning for OS division by decreasing the manning requirements on ships in port. Furthermore, it demonstrates that deployment manning levels can be improved given the current, undermanned distribution of OS Sailors in the fleet.

1.2 Motivation

As a sea-centric rate, OSs expect to spend more time at sea than on shore duty. They also expect to spend their sea tours assigned to a single ship executing the prescribed maintenance-workups-deployment schedule, as do all other sea-going Sailors in the Navy. However, that is not always the case for the most highly qualified OSs. Several factors contribute to the problem, including low sea-manning levels, extreme personnel tempo (PERSTEMPO) conditions while at sea, difficult schools required to attain the required qualifications, and little rate-specific work while in port. The result is some OSs assigned to one ship that is not deployed being cross-decked, or "lent," to another ship that is deployed, thereby increasing the amount of time those Sailors work in an increased PERSTEMPO environment and are away from their family and friends.

When ships are undermanned during deployment, the workload required of each Sailor increases proportional to the level of under-manning. The result is that OS Sailors stand "port and starboard" watches. Their off-watch time is used for sleep, workouts, messing, personal time, divisional work, and training. This schedule is often maintained throughout the entire deployment. The cross-decked Sailors do not alleviate the under-manning problem in the long-term. Rather, they are often brought in to bring an under-manned ship up to just the bare minimum number of qualified Sailors required in order to deploy, a number that is lower than the number of Sailors authorized for optimal execution of the rate's requirements.

When Sailors decide whether they want to pursue more advanced Navy enlisted classifications (NECs), they cannot ignore the reality that the qualification is likely to increase the time they spend on unplanned deployments. This in turn acts as to disincentivize Sailors from pursuing the qualifications. For the Sailors who choose to attend the school anyway, the attrition rate is high due to the difficulty of the school (Settles 2020). These two factors contribute to under-manning issues. Specifically, they contribute to the under-manning of Sailors with the critical skills of which ships require a minimum amount before the ship can redeploy.

Finally, the lack of meaningful and skill-specific work available for OS Sailors while in port can lead to apathetic or unsatisfied Sailors. This can negatively impact a Sailor's reenlistment decision. While in port, OSs are often seen polishing the same brass pieces throughout the ship every day. Or they are assigned to other divisions to support cleaning and preservation of the ship. This work is certainly important, but marginalizes a Sailor's enlistment expectations. The lack of repetitive skill-specific work may contribute to a decreased proficiency in the OS skill-sets, thus affecting a Sailor's performance on advancement exams. Sailors who continue to not advance eventually meet High Year Tenure policy limits and become losses to the Navy (Navy Personnel Command [NPC] 2020a). These losses contribute to manning shortages.

Currently, eligible Sailors can opt into the Sea Duty Incentive Pay (SDIP) incentive program, which is designed to increase the at-sea manning levels of the most qualified OS skills. However, this incentive program costs the Navy nearly half a million dollars each year (Jessie 2020), and the result is the current state of manning: under-manned.

1.3 Research Question

This thesis compares two concepts of operations for OS Sailor assignment, the status quo concept and the new surge concept, in order to determine whether deployment manning levels can be improved using a new concept of operations for detailing. It determines whether decreasing in-port manning levels to support surge command manning can result in increased manning for deployments given the current number of OS Sailors in the fleet.

In both concepts of operation, all Sailors spend their first sea tour assigned to a specific ship. For subsequent sea tours, they are assigned in the same manner in both concepts if the Sailor does not choose assignment to the surge command. However, when a Sailor chooses assignment to the surge command, they are not assigned to a specific ship. Instead, these Sailors are available to supplement a ship's assigned OS quota with qualified Sailors in order to attain the required number of Sailors for the deployment. When the deployment is over, the surge command Sailors return to the surge command, have a post-deployment rest period, then are available to support another deployment.

Deployed ships maintain the same manning requirements for both operating concepts. However, with the surge concept of operations, ships have different OS manning requirements while in port. When a ship is not deployed, the manning requirement decreases to just enough OS Sailors at each rating level to adequately contribute to in-port watch rotations, and the associated requirement of a full watch team able to get the ship underway. In order to accomplish this, the surge command manned with the authorized billets removed from in-port ships.

In order to compensate for the increased deployment frequency, assignment to the surge command counts as a sea tour but is only 24 months long. This allows the assigned Sailors to complete two deployments during their sea tour without the in-port periods of diminished productivity and skill atrophy.

The 24-month surge tour results in two deployments in a condensed period for surge Sailors. This could lead to Sailors not volunteering for the surge command, but the effect is mitigated by several advantages inherent in assignment to the surge command. First, the deployments are never a surprise, so families can plan and be prepared for the time away. Second, since there is no need for the surge command to have a centralized or specific location, satellite commands can be established at each of the Navy concentration areas. This give each Sailor a lot of flexibility regarding their preferred duty location. Whether their preference is to be sent to San Diego or to keep their family settled in Norfolk, the option is available through the surge command. Third, more time at sea is associated with increased promotability, both through the experience that comes with performing one's job and through board precepts that highlight arduous or challenging assignments for special consideration, as directed by Chief of Naval Personnel (CNP) (2019). Choosing assignment at the surge command can increase a Sailor's knowledge base and skill-set, and help the Sailor to stand out above their peers on selection boards.

Currently, Sailors reach 20 years of service, and thus retirement eligibility, at the end of their third sea tour. If a Sailor truncates their second sea tour by 36 months by taking an assignment to the surge command, their third sea tour takes them to only 17 years. Therefore, the final three years required to become retirement eligible are on a shore assignment. Overall, Sailors who retire at 20 years of service do three years fewer at sea, and three years more on shore than their peers who do not serve at the surge command. For Sailors who serve the maximum allowable 30 years, the three truncated years of sea duty are made up for by a three-year sea tour at the end of their career.

1.4 Thesis Outline

Chapter 1 introduces the thesis topic, including scope and motivation. Chapter 2 discusses background information and related research. Chapter 3 describes the models and the current (status quo) and proposed (Surge) system operations. Chapter 4 summarizes the results of the models. Chapter 5 discusses the implication of the results and suggests future work.

CHAPTER 2: Background and Literature Review

Sailors enlist in the Navy to perform a specific job. However, due to the nature of the military, there are fluctuating periods of high and low workload. For most Sailors, the fluctuations are relatively brief and never include a complete lack of skill-specific work. For some, though, their sea tours are made up entirely of periods of minimal work or periods of over-work. Chapter 2 discusses the background information relevant to Sailor utilization and studies and research related to Sailor workload.

2.1 Background

The United States Navy is a sea-going force, so when a Sailor enlists, there is an expectation of spending some duty time at sea. During their sea tours, Sailors work long hours, often with little sleep, little personal time, and little interaction with family and friends. This schedule is usually maintained for the duration of a six- to eight-month deployment, which occurs once or twice over the course of a four-year assignment to an operational ship (CNO 2014b). When the ship is not deployed, Sailors generally have plenty of maintenance, upkeep, and training to perform, which maintains their skills, but they also get to go home most nights and weekends.

As outlined in the OFRP (CNO 2014b) each ship follows a maintenance-workup-deployment cycle that spans three years. When an 18-month maintenance period is completed, a ship is available for deployments for the next 18 months. However, only about 8–9 of those months are preparing for or executing a deployment. During the remaining period before a deployment, the crew performs maintenance and training to maintain readiness conditions. Most rates onboard have skill-specific work to perform during these periods, even though the ship is in port. For example, information technicians must maintain the communication networks and computers regardless of the ship's status; and the ship's engineering division can light-off equipment for maintenance or proficiency without the ship being underway. Other rates, though, such as OSs and quartermasters, do not have major equipment to maintain, training is limited, and their skill-sets cannot be practiced while in-port. This leads to periods of under-utilization and skill atrophy for these Sailors.

All Sailors follow an alternating ship-shore duty assignment rotation, but different rates spend varying time periods at sea and shore. More sea-centric rates are associated with demanding work schedules at sea and less demanding work in port. For example, OS is a very sea-centric rating, so an OS who spends 30 years in the Navy has the following assignments: six months of initial training, 54 months of sea duty, 36 months on shore duty, 60 months of sea, 36 months on shore, 48 months of sea, 36 months on shore, 48 months of sea, then 36 months on shore (NPC 2019) (see Figure 2.1). During both the 54- and 60-month sea tours, a Sailor can expect two full deployments with the ship, though some Sailors end up doing only one deployment in that time. On a 48-month sea tour, a Sailor usually only deploys once with the ship (CNO 2014b).

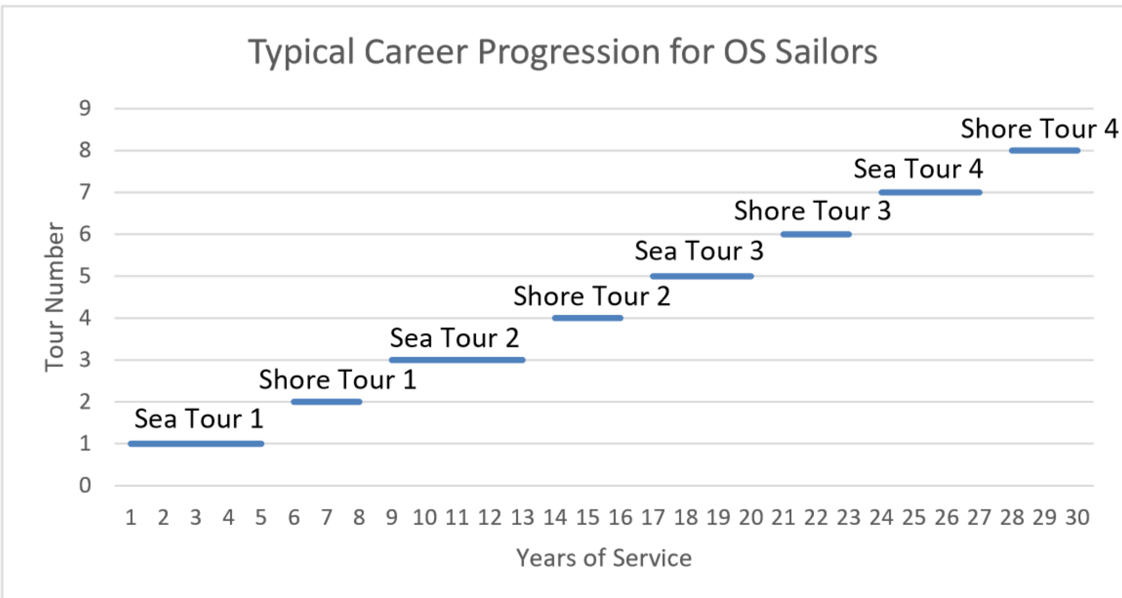

Figure 2.1. Typical Sea/Shore Rotation for Operations Specialist Sailors with 30 Years of Service. Adapted from Navy Personnel Command (NPC) (2020b).

2.2 Literature Review

Many studies have been done in recent decades that delve into the effects of over work and under work, and how Navy manning policies affect workload. This section discusses some of these studies.

2.2.1 Work Overload and Underload

Game (2007) demonstrates that high boredom in a job coupled with low boredom-coping skills can lead to non-compliance to safety standards and procedural violations, as well as less satisfaction with the job. When OS Sailors are in-port, they may not have rate-specific work that requires strict adherence to procedures, but life onboard a ship requires constant observation of safety standards and practices. Leaving Sailors bored (i.e., underloaded) for extended periods can increase their risk-taking (Game 2007), and, at worst, lead to accidents and further reduced manning. At best, these Sailors remain healthy and safe, but their job satisfaction diminishes (Game 2007), possibly leading to lower retention rates.

Hebb (1955) similarly concludes that lack of stimulation can lead to increased risk-taking and frustration, resulting in diminished ability to make reasonable decisions. He also discusses the other side of the spectrum: over-stimulation. The result of over-stimulation, or work overload, is similar to that of under-stimulation, namely the inability to make good decisions. This is especially relevant on a warship where emergency situations are necessarily a job expectation, if not a common occurrence. When Sailors are overloaded with daily work, they may not be prepared to make sound decisions when routinely practiced but out-of-the-norm things occur, such as a true man-overboard. And they may be unable to respond at all to major incidents like a hostile attack by another vessel.

For OS Sailors in particular, there is no period of optimal stimulation during a sea tour; they are either under-loaded in port or overloaded while deployed. As discussed by Game (2007) and Hebb (1955), this can lead to dangerous situations in which the affected Sailors are unable to perform their jobs as required in emergent situations, or boredom and lack of fulfillment, neither of which support retention, or are in line with the CNOs vision of taking care of our Sailors. Decreased manning in port distributes what little work there is between fewer Sailors, thus increasing in-port workload. Increased manning on deployed ships spreads the workload among more people, thus decreasing deployment workload. These two effects result in a more consistent workload distribution for OS Sailors.

2.2.2 Optimal Manning

In 2001, the Navy implemented an initiative called optimal manning. Optimal manning was intended to reduce ship manning levels to optimal levels for workload efficiency, thereby reducing personnel costs. In 2010, the Navy reversed course after determining that the initiative had adverse effects on ship readiness (Government Accountability Office [GAO] 2017). The effects were still felt in 2016 when Congress mandated the Government Accountability Office (GAO) review into the effects of ship manning policies. This report concluded, among other things, that "the Navy's Manpower Requirements process does not account for all ship workload," including in-port workload. Recommendations from the review include a reassessment of the Navy standard workweek as well as criteria for periodic reassessment, and examination of manpower requirements for in-port workloads.

The Navy Total Force Manpower Policies and Procedures document was updated by the Department of Navy in 2019 to reflect the need for periodic reassessment of Navy standard workweek and in-port manning requirements. The effects of these updates will take time to be felt due to new Sailor accession lag time. The result, though, may not address the mismatch of workload felt by OS Sailors.

2.2.3 The Unresourced Burden on United States Navy Sailors at Sea

Fletcher (2018) conducted interviews with subject matter experts and issued surveys to Sailors in the fleet in order to better understand and quantify the unresourced burden placed on Sailors at sea. Based on the responses, she discusses several areas in which a Sailor spends significant time on tasks that are not accounted for when determining how many Sailors are required onboard a ship. The areas include things such as waiting (in line, for a computer, for message routing, for HAZMAT disposal), looking for a single person necessary for a requirement (single point of failure), maintenance preparation, duplicate inspections, and emergent training and tasking. She also discusses the tasks that Sailors shed in order to accomplish their work. The shed tasks include sleep, exercise, healthful eating, religious ceremonies, cleanliness, cleaning and ship preservation, in-rate training, career development, mentoring/mentorship, and safety tasks.

Fletcher also identifies and quantifies routine maintenance requirements that are not accounted for in determining manpower requirements for ships, such as annual maintenance. Based on the number of these requirements and the amount of time they require to complete, she calculates an additional 10 to 17 manpower requirements. However, since those man-hours are not accounted for, it falls to the Sailors assigned to make up those required maintenance hours beyond their regularly accounted for time.

Many of the tasks that are shed to accommodate the work overload are things important in maintaining a healthy mental state and facilitating career progression. The unresourced burdens placed on Sailors are tasks beyond the Navy standard workweek. The combination of making up for under-manning and unresourced burdens requires Sailors to shed important personal care tasks, cut corners on safety, and/or perform their duties to the minimum possible standard. None of these results are in line with building a strong, capable and ready Navy.

2.2.4 An Analysis of Manpower, Personnel, and Financial Policy Decisions on DDG 51 Flight 1 Class Ships

Boschert (2018) reviews recent manpower, personnel, and financial policies and assesses whether they affected crew size, and if the policies had the desired results. He concludes that recent policies have improved Sailor productivity metrics without actually improving the workload of Sailors, or the policies have resulted in increased operational risk. Specifically, a 3-hour increase to the Total sailor workweek coupled with a decrease in make ready/put away and productivity allowances assigned more resourced burden on Sailors but did not change manpower requirements to match the increased burden. Thus, Sailor workload remained unchanged. With the implementation of Optimal Manning, authorized billets were reduced, but the workload, again, remained unchanged. The discrepancy was accounted for, concludes Boschert, through an increase in operational risk.

In analyzing the changes to manning as policies changed, Boschert notes a disparity between the number of Sailors assumed to be onboard (current onboard [COB]), and the number actually present onboard (present at quarters [PAQ]). A Sailor may be considered COB, but not actually be PAQ due to situations such as temporary assignment to training facilities or the Sailor being on leave. The difference between the two levels of manning account for an increased workload for those actually PAQ. Boschert calculates that 6.6 extra hours of work are required by those PAQ to make up for the COB Sailors who are not PAQ. However, that does not account for the extra hours required to make up for under-manning issues. When all is accounted for, each Sailor requires over 20 hours more per week to complete all required work. That is on top of their own Navy standard workweek hours (Boschert 2018).

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CHAPTER 3:
The Model

Chapter 3 describes the way in which Sailors move around the fleet throughout their careers in both the current system and in the proposed new system. It also discusses the model-types used to simulate Sailor and ship movement over time. This chapter also describes the assumptions and design associated with the model used for analysis.

3.1 Model Overview

The discrete event simulation (DES) model, referred to as the Fleet Movement Model, simulates how Sailors move around the fleet throughout their careers, and how ships move through availability periods and deployments. the Fleet Movement Model tracks and collects statistical data for comparative analysis when using differing input parameters.

3.1.1 Discrete Event Systems and Discrete Event Simulations

As discussed by Schruben and Schruben (2009), a discrete event system is one in which simulated time does not run continuously. Rather, the system progresses based on events of interest. Events of interest result in a state change for one or more of the system states. These events are scheduled on an event calendar, and when one event is complete, the system jumps to the next scheduled event. Time intervals with no events are skipped in discrete event systems, making these systems useful in modeling large systems. A DES is a model of a discrete event system (Schruben and Schruben 2009). An event graph is a graphical representation of a the system modeled by a DES. A more detailed discussion on how event graphs work can be found in Appendix A.

3.1.2 DESpy

DESpy is a package designed by Dr. Arnold Buss for use in Python to implement event graph models. From Buss (2018, p. 2), “it provides an Event List for scheduling and executing events, a base class for defining Event Graph models, many of the standard probability distributions, and some classes for computing simple sample statistics from simulation experiments."

Buss (2019) discusses transient entities. DESpy tracks the movement of individual components throughout the model by using transient entity objects. Each object carries certain attributes which can be updated as the object moves through the system and can be used in scheduling events (Buss 2019).

3.2 Concept of Operations

The Fleet Movement Model models two methods of distributing Sailors to a sea tour, the status quo method and the proposed surge method. The two concepts are discussed in detail in sections 3.2.1 and 3.2.2. The advantages associated with the new surge concept of operation are detailed in Section 3.2.3.

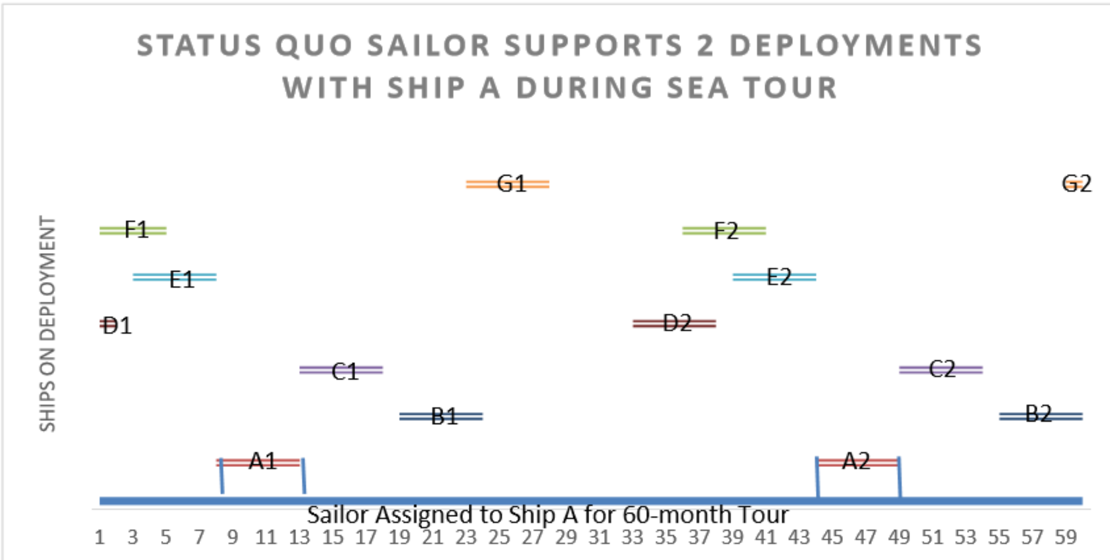
3.2.1 Status Quo

As the distribution of Sailors works now, when a new OS Sailor is ready to enter the fleet, their detailer will determine where they are most needed. Each Sailor's individual preferences are considered; ultimately, the needs of the Navy come first (CNP 2012). Once assigned to a ship, the Sailor remains attached to that ship for the duration of their orders, usually four or five years (Navy Personnel Command (NPC) 2020b). While on the ship, the Sailor works on earning qualifications to support the OS divisional watch-standing responsibilities. Once a given level of qualifications is attained, further achievement requires formal schooling which can be several months long and has a high attrition rate (Settles 2020). If a Sailor chooses to pursue these qualifications, they may be sent to school while still attached to their ship, or they may attend the school between duty assignments, prior to reporting to a new ship.

There are often fewer Sailors with these advanced qualifications than are needed on the ships throughout the fleet. This is due to two main factors: the high attrition rates for the schools, and the expected quality of life for the Sailors who attain these qualifications. High attrition is an expected part of a highly skilled qualification and therefore is not addressed in this thesis. Sailor quality of life, on the other hand, is something that can be changed. When a Sailor has an in-demand qualification, they are often called upon to support deployments beyond those of the ship to which they are assigned. This "borrowing," or cross-decking, of Sailors in order to meet minimum manning levels for deployment places an unequal burden on those Sailors who excel in their careers. It can also cause unpredictability in their lives when they know they may be sent on a deployment with little advanced notice during periods when they expect a relatively predictable in-port daily schedule.

When Sailors begin a new sea tour rotation, they can expect to deploy one or two times during a four- or five-year tour. However, a single deployment is not the norm, so most Sailors can expect to spend 12 to 18 months deployed per sea tour. Those who only deploy once can expect to spend six to nine months deployed. The rest of their time onboard is spent not utilizing their skills because the skills are not relevant to in-port operations (see Figure 3.1). When a highly qualified Sailor is cross-decked to another ship for deployment, their skills get used more, but they end up spending an extra six to nine months underway each time they are "lent" out. Furthermore, even when accounting for borrowed Sailors, the OS manning levels are below ideal, so the Sailors work longer hours than programmed for throughout each deployment. This affects all OSs, and leads to an imbalanced workload between in-port and at-sea periods, but it leads to significantly more over-worked periods for the highly qualified Sailors. Sailors without the qualification who remain with their own ship are under-worked while in port, potentially resulting in under-load and boredom, but more time for home and personal life. The skew for highly qualified Sailors towards over-work, including greater than 80-hour workweeks, little sleep, and extended time away from family and friends, can act as an incentive against Sailors trying to attain higher qualifications, thus further exacerbating the under-manning problem. The increased time at sea undoubtedly leads to improved advancement opportunities for these Sailors, but the advantages are weighed against the significant disadvantages when a Sailor considers whether to reenlist.

When a Sailor completes their sea tour, they are assigned to a shore tour for three years, during which they do not deploy. However, if the Sailor has a critical qualification, they may be eligible for SDIP, in which, in exchange for monetary compensation, they elect to skip their shore rotation and go straight to another ship assignment. The Navy spends half a million dollars on this incentive programs each year (Jessie 2020), and the result is the current state of the fleet, which still includes undermanned ships and the need to borrow qualified Sailors to support deployments.



In this figure, ships A-G each deploy two times. When a Sailor is assigned to a single ship, in this case ship A, for a full 60-month tour, they will only support deployments for that ship. This results in a lot of under-utilized time throughout the tour while the ship is not deployed. Note that if the Sailor were assigned to ship D or G, that Sailor would be doing only one full deployment during their tour.

Figure 3.1. Status Quo Concept of Operations

3.2.2 Surge

With the establishment of a surge command, detailing for new OS Sailors remains the same. After a Sailor's first sea tour, they become eligible to attend schooling for a critical qualification. If they have or are willing to attain the qualification, they are eligible for assignment to the surge command. Assignment to the surge command counts as a normal sea tour, and thus is proceeded and followed by assignment to a shore tour, according to standard sea-shore rotations. However, rather than 60- or 48-month orders, as is the standard rotation length for a second and third sea tour, respectively, Sailors serve for only 24 months at the surge command.

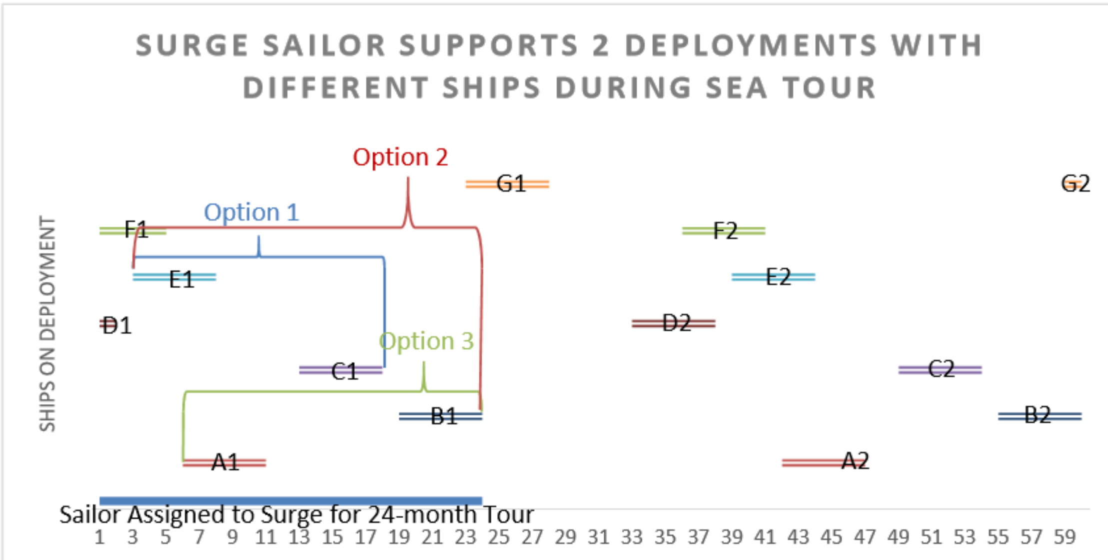
Sailors not electing or not eligible for assignment to the surge command are detailed to ships according to the current status quo method of detailing. However, there are fewer authorized billets required onboard each ship. This allows for a surplus of authorized billets to accommodate the surge command. With fewer assigned Sailors, there are fewer under-utilized man-hours for in-port ships with minimal demand for OS in-rate skills. When a ship prepares to deploy, it supplements its manning by drawing from the surge command. Sailors assigned from the surge command to the ship complete pre-deployment workups with the ship and remain onboard throughout the deployment. Upon return from deployment, the surge Sailors return to the surge command and be eligible to supplement another deployment.

According to the Navy Personnel Tempo and Operating Tempo Program guidance (CNO 2014a), after a Sailor deploys, they must get enough time off before the next deployment to make a minimum 1:1 ratio of deployment-to-time-off. To accommodate this, when a surge Sailor returns from deployment, they are ineligible to support another ship's deployment for three months. After the three-month break, the Sailor spends two to three months assigned to a ship for the ship's pre-deployment workups. This results in six months between deployments. If a Sailor does not have enough time remaining at the surge command to support the full duration of a ship's planned deployment, they are not eligible to support that ship's deployment. In this framework, a Sailor at the surge command can expect to support two deployments during their surge command sea-tour rotation (see Figure 3.2).

3.2.3 Advantages of a Surge Command

A Sailor on a typical status quo sea tour would also expect to complete only two deployments with their assigned ship, not including time deployed with other ships to which they may be cross-decked. In this sense, the surge Sailors will likely spend the same amount of time at sea as their peers not assigned to the surge command. However, there are additional advantages that come with assignment to the surge command that could make the condensed deployment time worthwhile for some Sailors. The first advantage is that the deployments are expected and can be planned for. When a Sailor is assigned to a ship for a regular sea tour, and they have the critical qualifications, they know that they may be sent to support another ship's deployments with little notice or time to prepare. This uncertainty can have a negative impact on the Sailor, their family, and their personal pursuits. Electing assignment to the surge command effectively condenses their sea tour and all the deployments they would likely face into a shortened, predictable time period.

A second advantage is how a surge command is structured. Since the surge Sailors can be assigned to any ship in need of supplemental manning, it does not matter where the



In this figure, ships A-G each deploy two times. When a Sailor is assigned to the surge command for 24 months they support two deployments on different ships. In this case, the Sailor can support deployments E1 and C1, E1 and B1, or A1 and B1. This results in a condensed sea tour with little under-utilization.

Figure 3.2. Surge Concept of Operations

surge Sailor is physically located while awaiting assignment to a ship. Since there is no specific responsibility placed on surge Sailors between deployments, it does not matter where the surge command is located. Therefore, a surge location can be established at each of the major fleet concentration areas, and Sailors electing orders to the surge command can choose whichever location they prefer. This can give Sailors increased options and flexibility in when and how their family uproots and moves. A Sailor leaving a shore tour in San Diego, for example, may find that they would be assigned to a ship in Norfolk if they chose a conventional sea tour. So, they may elect assignment to the surge command so they and their family can remain in San Diego.

A third advantage is a concentrated time at sea to improve a Sailor's chances of promotion. This would benefit both Sailors who advance strictly by exam results, and Sailors selected by a board. Time at sea and a willingness to accept orders to assignments with higher operational temp are associated with increased in-rate knowledge and viewed favorably by advancement boards (CNP 2019).

When surge Sailors are not supplementing a deployment, they can spend their time on military requirements such as General Military Training, further professional qualifications, militarily encouraged pursuits such as advanced education, mentoring of junior fleet Sailors, and community relations, such as volunteer service and outreach.

3.3 Simplifications

As a POC, the Fleet Movement Model represents simplifications of actual fleet manning, Sailor movement, and ship schedule characteristics. Simplifications fall into two broad categories: Sailor-related and ship-related.

3.3.1 Sailor Simplifications

OSs can earn a range of NECs throughout their careers in order to support operations on various platforms as well as to increase their responsibilities and knowledge level on any particular platform. The Fleet Movement Model does not specify Sailor qualifications and treats each Sailor onboard a ship as qualified to perform all necessary OS-related job tasks. However, the Fleet Movement Model does include Sailor rank, which can be used as a proxy for qualifications by ensuring the Fleet Movement Model does not rely on manning ships with Sailors too junior to have the necessary qualifications for deployments.

The Fleet Movement Model also simplifies the movement of Sailors around the fleet to force a fixed rotation between sea duty and shore duty, with sea duty assignments either to a ship or to the surge command. In reality, Sailors may deviate from the fixed sea-shore rotation, to include doing back-to-back sea tours, or assignment to duty other than sea duty for extended periods for special circumstances. SDIP is a monetary incentive program to encourage Sailors to opt for back-to-back sea duty in order to help improve manning on ships. Excluding the effects of such incentives in the Fleet Movement Model helps to demonstrate the feasibility of the concept as an alternative to simply "throwing money at the problem." With this simplification, the Fleet Movement Model can better demonstrate to what extent the surge command can ease under-manning problems.

When assigning a Sailor to a ship, the Fleet Movement Model bases the decision on current manning levels, prioritized by ship phase, and how long the ship has been in its current phase. In reality, a detailer would consider a combination of a ship's near-term schedule, its current manning levels, the Sailor's preferences, and available funding when assigning Sailors to ships. This simplification is necessary in order to create a model of personnel movement that is not exceedingly complicated for a POC. Any improvement demonstrated by the Fleet Movement Model will indicate a successful POC; when including the work of detailers in the assignment process, the results will be further improved. Data from the fleet movement DES model can be fed into an optimization model (see Appendix B) to demonstrate the further improvements that can be seen in deployment manning levels when a detailer decides which ship most needs and available Sailor (human-in-the-loop improvements).

3.3.2 Ship Simplifications

The scope of this analysis is limited to the DDG 51 FLT I (destroyer) platform, so the Fleet Movement Model is simplified in that all ships have identical manning needs and authorized billets. Sailors in the Fleet Movement Model rotate between these ships and shore duty and never exit the modeled system for assignment to a different platform. This simplification has little impact on the results because in a more realistically modeled system, each Sailor would leave the system for a different ship-type, causing another Sailor to enter the system.

Similar to the fixed Sailor rotation, the Fleet Movement Model also simplifies the ships' schedule to a fixed rotation of available-for-deployment and not-available-for-deployment. Only ships that are available for deployment can be called to deploy, and they will complete their scheduled deployment, regardless of whether they shift to a not available status during the deployment. Ship schedules are not impacted by maintenance delays or emergent operational needs. Further, every time a ship returns from deployment, the Fleet Movement Model immediately schedules another deployment. In reality, there is not always a one-for-one swap on deployments, and deployments may overlap for a period to allow continuity on station. These simplifications do not affect the results of the POC and whether the surge command allows for better Sailor utilization.

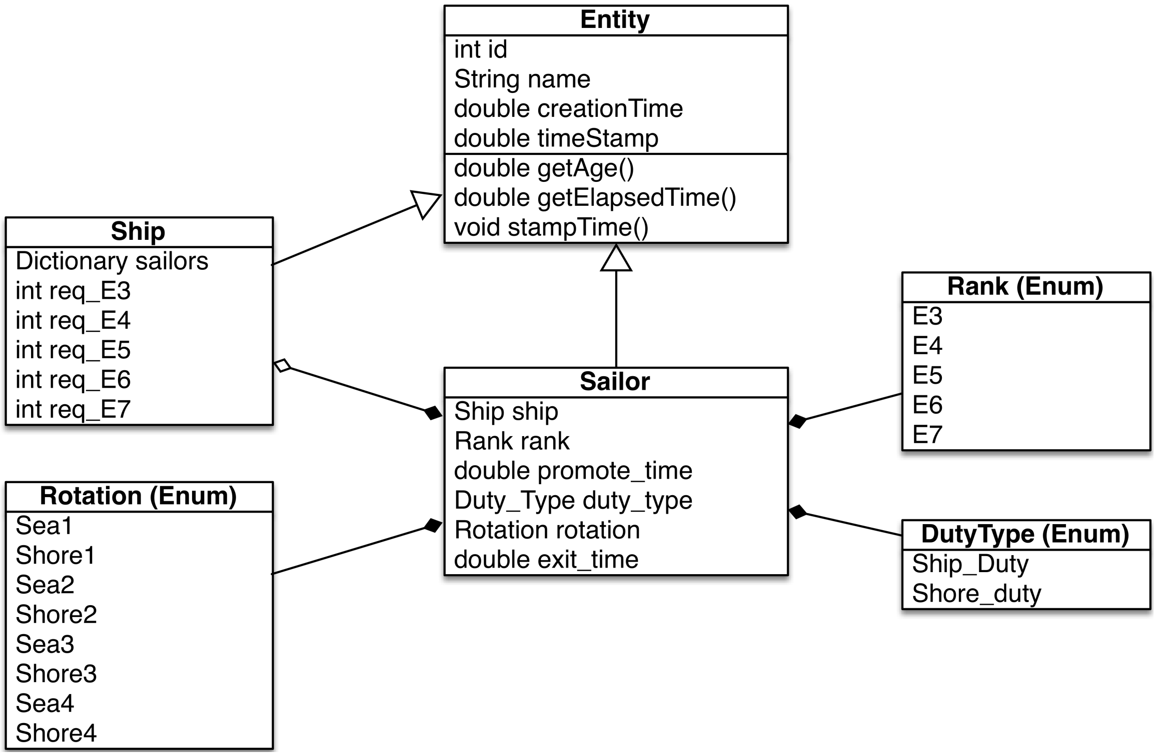
For real-world deployments, there are minimum manning requirements. If the minimum requirements are not met, a ship will supplement by "borrowing" the necessary Sailors from other ships. the Fleet Movement Model does not enforce minimum manning requirements for deploying ships. This simplification allows the Fleet Movement Models to show true changes to manning levels during deployments.

3.4 Discrete Event Simulation Model Description

the Fleet Movement Model models the fleet of Sailors and Destroyers as entity subclass objects according to the defined simplifications. Each entity object has inherent methods that allow for time-tracking, such as "time stamp," and "get elapsed time." Sailor objects enter and leave service, promote, rotate between sea- and shore-duty, and sometimes take assignment to the surge command. Destroyers (i.e., ship objects) rotate between available-for-deployment and not-available-for-deployment, with deployments assigned from the list of ships available to deploy. All of these events are stochastically determined by the Fleet Movement Model.

Each Sailor object contains attributes defining the Sailor's current paygrade, their next promotion, when they leave service, their current duty assignment, and when they rotate to their next assignment. Each ship object contains attributes defining manning level, availability status, and deployment timing. Each Sailor object is assigned to a ship object. Each ship object contains the paygrade of each Sailor assigned. When a Sailor promotes, the manning levels for the old and new paygrades are updated on the ship to which the Sailor is assigned. When a Sailor rotates, their duty type, rotation, and ship update and the Sailor rank count for the ship to which they were assigned updates. Figure 3.3 shows the ship and Sailor attributes and their interactions.

Using the object attributes and entity methods, the Fleet Movement Model collects the average deployment manning levels and time-average manning levels for each OS paygrade. Time-average manning levels are determined by tracking the amount of simulated time at each manning level, then dividing the summed level-time value by the total simulated time. Since the state trajectories in a DES model are piecewise constant, the summed level-time value is the area under the state-value curve. the Fleet Movement Model also collects a reward value based on the manning level for each deployment. Whereas the average deployment manning level is an average over all deployments, the reward value is an aggregate of each individual deployment. This allows for a simple indication of changes in manning as the surge percent changes, but it also allows for the results of the Fleet Movement Model to be compared to the results of an optimization model. The optimization model in Appendix B



Ship and Sailor objects are entity subclasses (open arrows). Each Sailor object has a rank, a rotation, a duty type, and a ship (black diamonds). Each ship object stores Sailor information by Sailor rank (white diamond).

Figure 3.3. Ship and Sailor Attribute Interactions

maximizes the value of reward, calculated in the same way as the Fleet Movement Model.

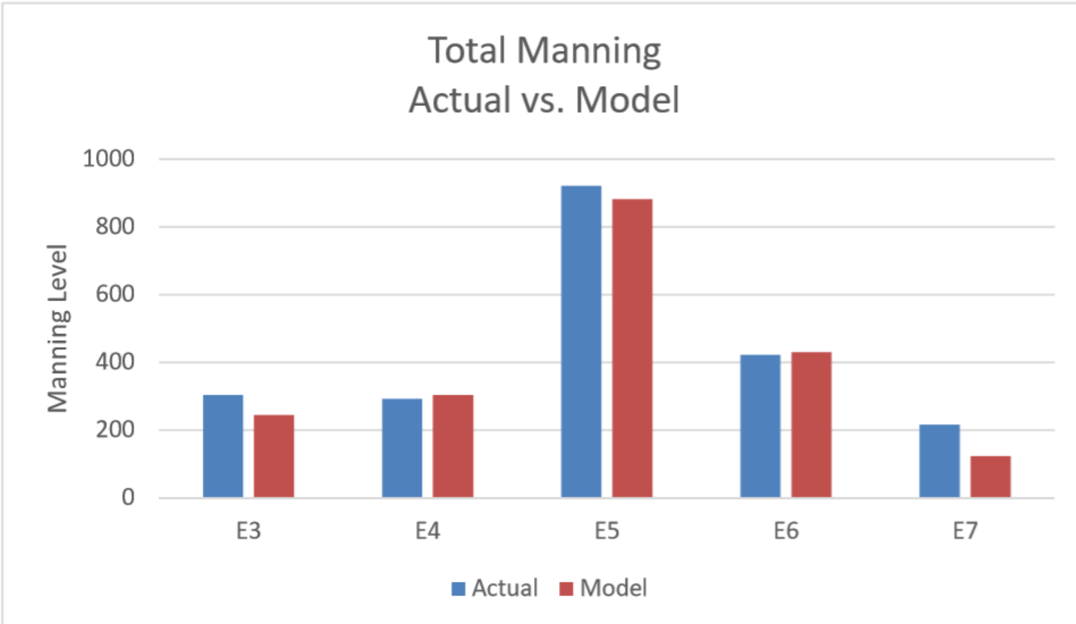
The Fleet Movement Model executes events until the simulated time reaches 1200. As designed, each time increment represents one month, so the Fleet Movement Model simulates fleet activities for 100 years. This period of time allows for initial fluctuations to steady and for the system to reach steady state. the Fleet Movement Model sends some percentage of eligible Sailors to the surge command, based on input parameters. If the percentage of eligible Sailors is set to zero, the Fleet Movement Model simulates the status quo system. A Sailor is deemed eligible for the surge command when they are on any sea tour after their first one and have not been assigned to the surge command before (i.e., Sailors are only eligible to serve at the surge command once in their career). In order to compare the effects of the surge command, the Fleet Movement Model is run for various values representing the percentage of eligible Sailors assigned to the surge command. The percentage value starts at zero, representing the status quo system with no surge command, then is increased in ten percent increments until one hundred percent of eligible Sailors get assigned to the surge command. For each percent increment, the Fleet Movement Model is run for 30 independent replications.

Each replication collects the sum of reward levels for all deployments as well as data to feed into the optimization model and data for use in validation. The Fleet Movement Model is proved to be an accurate representation of OS career progression by observing the distribution of Sailors, both by rank and by type of assignment (i.e., sea or shore), to be similar to the current distribution of Sailors in the fleet (NPC 2019). The matched distributions indicate that the Fleet Movement Model simulates movement around the fleet in a realistic manner (Figure 3.4).

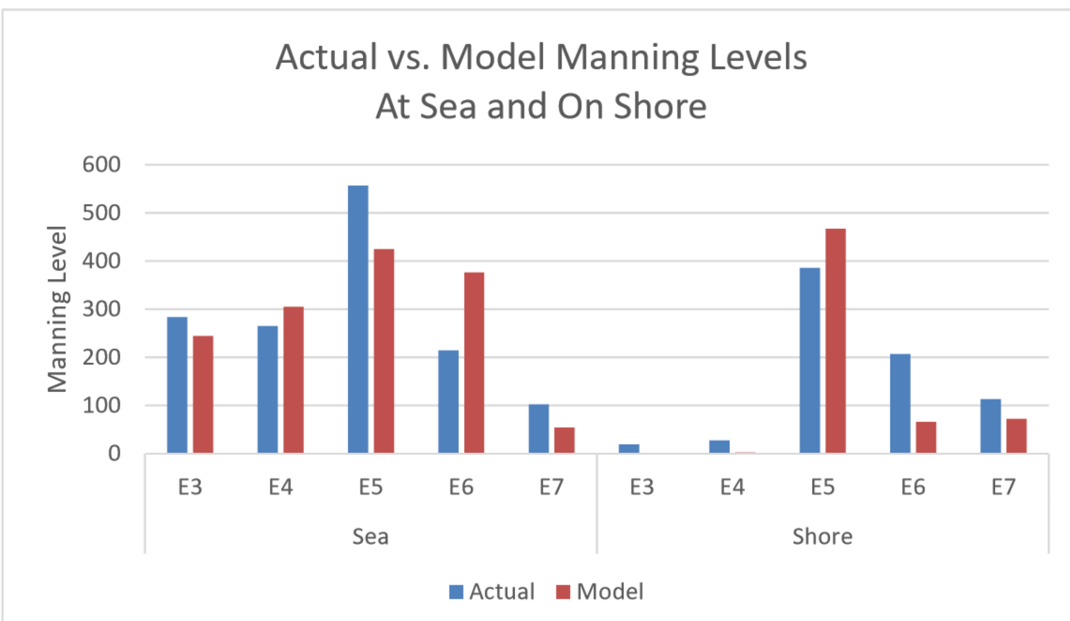
Of note in Figure 3.4(b) is the difference in E5 and E6 levels for sea and shore tours. The actual current distribution has more E5s at sea than does the Fleet Movement Model, and fewer E6s at sea than the Fleet Movement Model. The opposite is seen on shore duty, with the Fleet Movement Model showing more E5s and fewer E6s than in actual current distribution. This can be explained by the availability of incentives in the actual fleet targeted towards E5 Sailors. SDIP increases E5 manning levels at sea, therefore shifting shore duty to later in a Sailor's career, thus resulting a higher fraction of E6 Sailors on shore duty. The Fleet Movement Model does not model SDIP so the effects are not expected to be seen in the Fleet Movement Model results. Similarly, the Fleet Movement Model does not account for junior Sailors (i.e., E3 and E4 Sailors) that are assigned to shore duty prematurely, which can happen for a number of reasons including injury or special circumstance. Because of this, the Fleet Movement Model shows fewer junior Sailors on shore duty than is currently the case. Finally, this thesis is not concerned with the senior-most Sailors (e.g., E7), so the Fleet Movement Model ends the career of senior Sailors earlier than is likely, in reality; so there are fewer E7 Sailors in the Fleet Movement Model than there are in the actual fleet.

3.4.1 The Ships and Their Schedules

The Fleet Movement Model uses 62 ships (representing the 62 DDG-51 Class Destroyers currently in the fleet) rotating through periods of availability, including not-available-to-



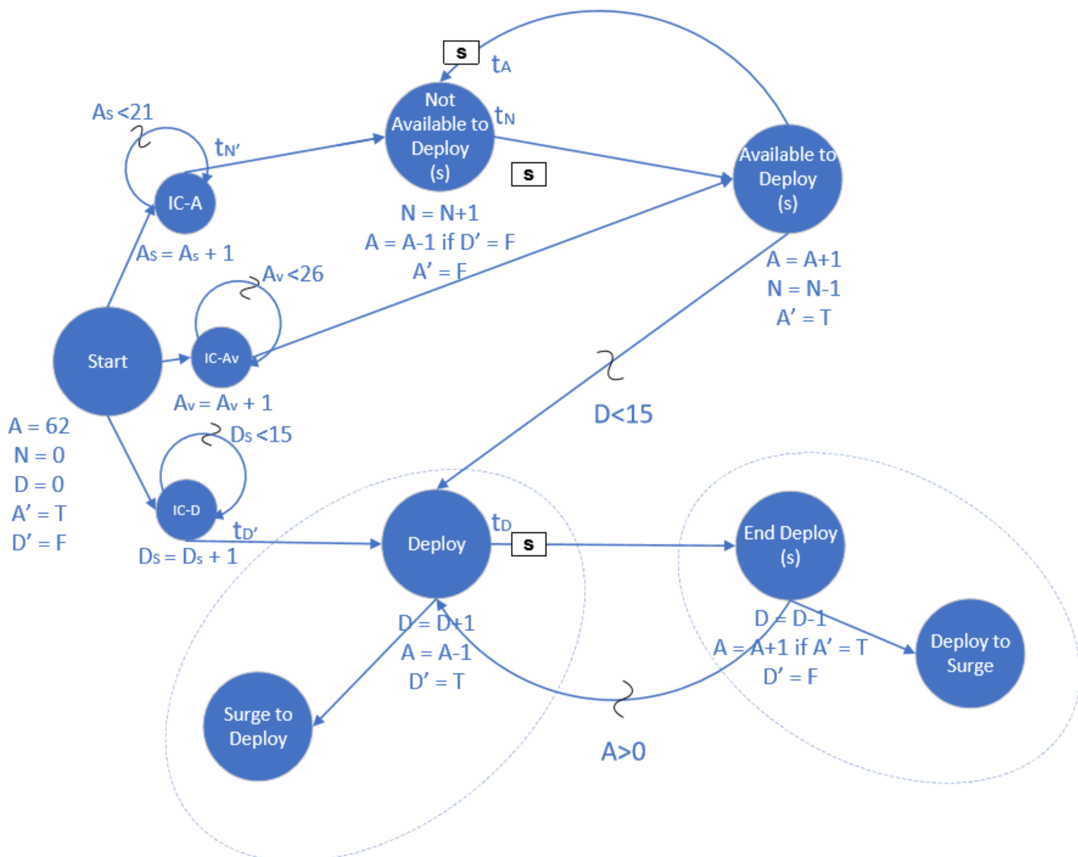
(a) Overall Distribution of Sailors by Rank



(b) Distribution of Sea and Shore Sailors by Rank

Figure 3.4. Comparison of Actual Current Sailor Distribution by Rank Versus Model Distribution. Adapted from NPC (2020b).

deploy, and available-for-deployment. For the purpose of this model, the start of a deployment is not a separate period of availability as it is in the OFRP (CNO 2014b). Rather, it is an event that can occur at any time when a ship is in the available-for-deployment period. See the deployment event in Figure 3.5.



At the start, all ships are routed to either Available for Deployment (A), Not Available for Deployment (N), or Deployment (D). A ship beginning deployment prompts a surge of Sailors from the surge Command. When a deployment ends, the surge Sailors return to the surge Command and a new deployment is scheduled. Ships rotate between Available for Deployment and Not Available for Deployment.

Figure 3.5. Ship Phase Event Graph

The amount of time each ship spends in each availability phase is based on the OFRP (CNO 2014b) and each period is simplified for the Fleet Movement Model to be a triangular distribution, with a mode of 18 months and a max of 24 months. The not-available-for-deployment period has a minimum of 12 months, and the available-for-deployment period has a minimum of 15 months. the Fleet Movement Model starts by sending 15 ships from the ships available for deployment on deployments. Deployment lengths are modeled as a gamma distribution with a mean of 6.5 months and a variance of 1.5 months. This is an assumption based on the expected deployment length as defined in the OFRP.

When a ship ends a deployment, another ship immediately deploys in its place, as long as there is a ship available. This results in, on average, 15 ships always being deployed. Upon return from deployment, if a ship is still in the available-to-deploy period, it is not be eligible for another deployment until three months have passed. This assumption is based on the minimum time between deployments that Sailors are allowed, per CNP (2019) guidance.

3.4.2 The Sailors

the Fleet Movement Model starts with Sailors assigned to each ship at the current manning levels. The current level is based on the percent manning for each rank of OS Sailors on sea duty, as published in the OS community overview (NPC 2019). The community overview identifies the number of authorized billets for each rank of OS Sailors assigned to sea and shore duties, as well as the current manning levels to each duty type. The DDG 51 FLT I Ship Manpower Document Navy Manpower Analysis Center (NAVMAC) 2018 document identifies how many billets are authorized onboard such ships. The Fleet Movement Model assumes that each Destroyer is manned at the same percentage-level as the at-sea OS Sailors across the fleet. Using this standard, each ship in the Fleet Movement Model starts with 3 OS seaman (OSSN) Sailors, 5OS3 Sailors, 10 OS2 Sailors, 3 OS1 Sailors, 1 OS chief (OSC).

There are also 732 Sailors assigned to shore duty for the start of the Fleet Movement Model. the Fleet Movement Model does not track specific shore duties, but the shore duty shell is used to hold Sailors while they are between sea duty assignments. 732 is used as the initial manning level based on the community overview and the ratio of authorized OS DDG billets to total authorized OS sea billets. There are 4957 authorized OS sea billets, of which 1,736 are designated for DDGs, or 35%. The ratio is assumed to also represent the fraction of shore billets filled by Sailors who serve on Destroyers. Therefore, for each rank of actual OS Sailors on shore duty, 35% of the value was used for that same rank in the Fleet Movement Model. OS3 are not included on shore duty for the start of the Fleet Movement

Model because the Fleet Movement Model assumes that each Sailor serves their first tour on a ship.

Sailor Progression through Career

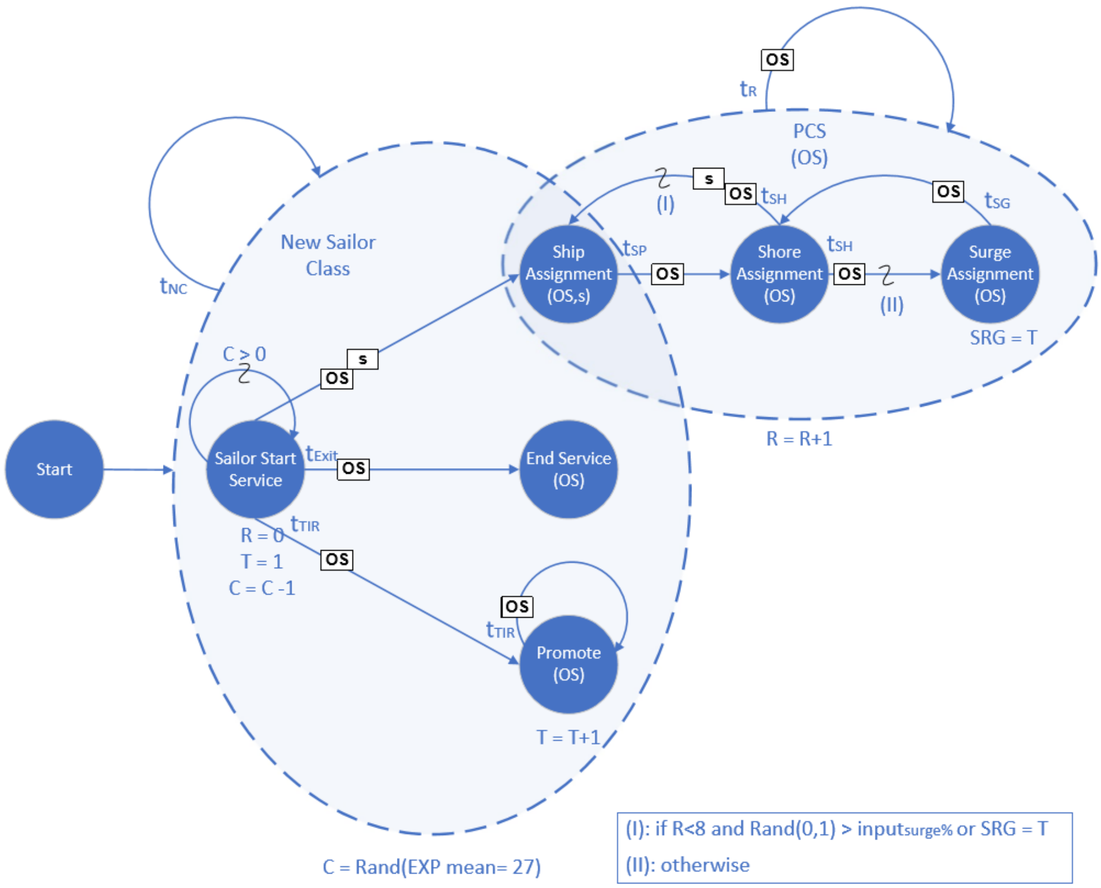
Periodically, a group of new OS Sailors enters the fleet. It is assumed that they are all OS3 and have completed all initial training. When they enter the Fleet Movement Model, they are assigned to a ship and begin their first duty rotation. the Fleet Movement Model uses a triangular distribution to determine when a new class of Sailors arrives, with the minimum time between arrivals and the mode both being one month. The maximum time between a new arrival is 4 months. The size of the new class is an exponential distribution with a mean of 30. These values are based on an interview with the OS Community Manager (Settles 2020). See Figure 3.6

Each Sailor that enters the fleet is assigned the time at which they will leave the fleet. This time-in-service is modeled as triangular distribution with a mode of 96 months, a minimum of 54 months and a maximum of 240 months. These values are based on the attrition rates as shown in the OS community overview (NPC 2019).

The time until a Sailor promotes is a triangular distribution based on their current rank. OSSN Sailors promote with a mode of 12 months in rank and a minimum of 12 months and maximum of 24 months. OS3 Sailors promote with a mode of 12 months in rank and a minimum of 12 months and maximum of 36 months. OS2 Sailors promote with a mode of 66 months in rank and a minimum of 36 months and maximum of 80 months. OS1 Sailors promote with a mode of 55 months in rank and a minimum of 48 months and maximum of 66 months. For the purposes of this model, no Sailor promotes past OSC. These values are based on the OS community overview (NPC 2019) and an interview with the OS community manager (Settles 2020).

Sailor Movement through the Fleet

Upon entering the fleet, each Sailor is assigned to a ship based on the following hierarchy: deployable ships not deployed, ships not available for deployment, deployed ships. The length of time a Sailor spends at a tour before rotating is based on the expected tour length for each OS tour (NPC 2020b). For the Fleet Movement Model, each rotation time is a



Two main scheduled events trigger multiple sub-events: New Class of Sailors enters the fleet and a Sailor PCSs. When a new class enters, each Sailor in the class gets scheduled a promotion and a time to exit the fleet. They also get assigned to a ship. Ship assignment triggers a PCS event in which the Sailor moves between ship and shore assignment, with the option of surge assignment during a ship tour.

Figure 3.6. Sailor Movement and Career Progression Event Graph

triangular distribution. Based on the NPC 2019 sea/shore rotations, the first sea tour has a minimum of 51 months, a mode of 54 months, and a maximum of 66 months. The second and third sea tours have a minimum of 57 months, a mode of 60 months, and a maximum of 72 months. The fourth sea tour has a minimum of 45 months, a mode of 48 months, and a maximum of 60 months. Each shore tour has a minimum of 30 months, a mode of 36 months, and a maximum of 42 months. the Fleet Movement Model assumes that Sailors rotate between sea and shore duty without deviation. Based on the mode length of each tour, a Sailor would reach thirty years of service during their fourth shore tour, thus the Fleet Movement Model does not allow Sailors to go beyond thirty years of service.

When a Sailor transfers from shore duty to sea duty, they are assigned to whichever ship has the fewest Sailors of the same rank. The hierarchy in case of a tie is ships deployed, ships deployable but not deployed, then ships not deployable.

Surge Command

When the fraction of eligible Sailors who are assigned to the surge command is greater than zero, the initial manning level of ships is decreased to 3, 5, 5, 2, and 1, for OSSN, OS3, OS2, OS1, and OSC Sailors, respectively. The initial manning level for the surge command is 372, accounting for the six fewer Sailors assigned on each of the 62 ships.

Sailors from the surge command are temporarily assigned to a ship for the duration of the ship's deployment. The number of surge Sailors assigned is equal to either the number of Sailors needed to fully man the ship for deployment (28 (NAVMAC 2018) minus the number of Sailors currently assigned to the ship), or all the Sailors available to deploy from the surge command, whichever is lower.

When a ship returns from deployment, the surge Sailors return to the surge command, but they will not be eligible to supplement another deployment until they have been back for at least three months. This ensures surge Sailors have the required amount of time between deployments as required by CNO (2014a).

When a Sailor completes a tour at the surge command, they are no longer eligible to be assigned to the surge command for future sea tours. Instead, they will serve all future sea tours assigned to a specific ship.

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CHAPTER 4:
Results

The DES model simulates the movement of Sailors around the fleet throughout their careers and the movement of ships throughout their maintenance-deployment cycles. It demonstrates both the current model of Sailor movement and the proposed surge model in order to establish a POC for the new method. Chapter 4 discusses the model results and the success of the POC.

4.1 Results

As a simulation of a subset of the fleet, the DES model has two basic measures of effectiveness (MOE): a reward value based on the total number of OS Sailors assigned to each deployment, and the average number of OS2 Sailors assigned to each deployment. Both MOEs show an improvement as the fraction of eligible Sailors who choose assignment to the surge command increases.

4.1.1 Deployment Total Manning: Reward Value

We calculate the reward value z for each deployment based on the number of Sailors assigned to that deployment S (Equation 4.1). If 21 or more Sailors are assigned to a deployment, then a reward of of $\frac{1}{i}$ is obtained for the i^{th} additional Sailor beyond 21. Let N denote the total number of Sailors assigned to a deployment beyond 21 (i.e., S=21 + N). Then,

$$z(S) = \begin{cases} 0, & \text{if } S \leq 21 \\ \sum_{i=1}^{N} \frac{1}{i}, & \text{if } S = 21 + N, \text{for } N > 0. \end{cases} \tag{4.1}$$

From the model, with about 2,765 deployments completed per model run, the reward level steadily increases from zero surge Sailors (status quo) to 100% of eligible Sailors opting for assignment to the surge command (Figure 4.1).

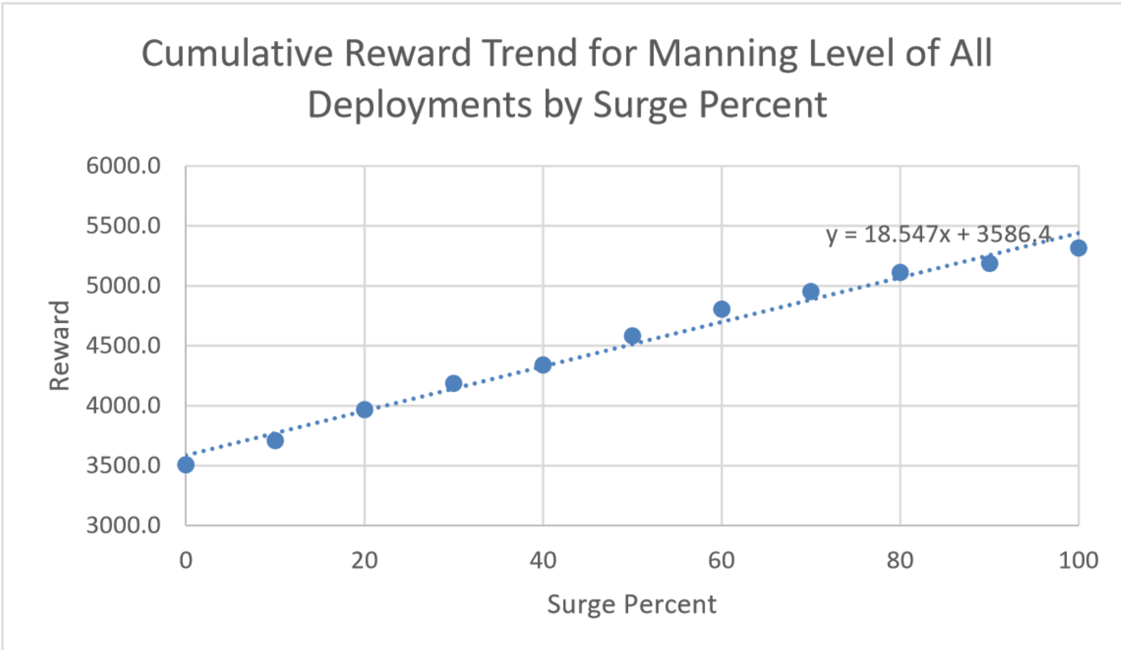

Figure 4.1. Trend in Deployment Reward as Surge Percent Increases

4.1.2 OS2 Manning: The Sailors

As expected based on the reward trend line, the OS2 manning increases by about two Sailors from 0 to 100% surge utilization. Since surge Sailors do not complete more deployments than is the norm for a status quo tour, deployment manning is not expected to increase much. However, Figure 4.2 demonstrates that there is a lot of variation in the results from each individual model run. The increase that is seen is caused only by the extra deployments completed by Sailors who would have only done a single deployment had they done a regular sea tour.

The average improvement over all runs is an increase of 1.8 Sailors per deployment with a standard deviation of 0.4 Sailors. This indicates that the surge command can improve OS deployment manning by, on average, 1 to 2.6 Sailors when all eligible Sailors choose assignment to the surge command only once in their career. Allowing more than one surge tour per career would amplify these results.

The fleet movement model does not take into account the human-in-the-loop effect that a detailer provides when deciding to which ship a Sailor should be assigned. It is reasonable to

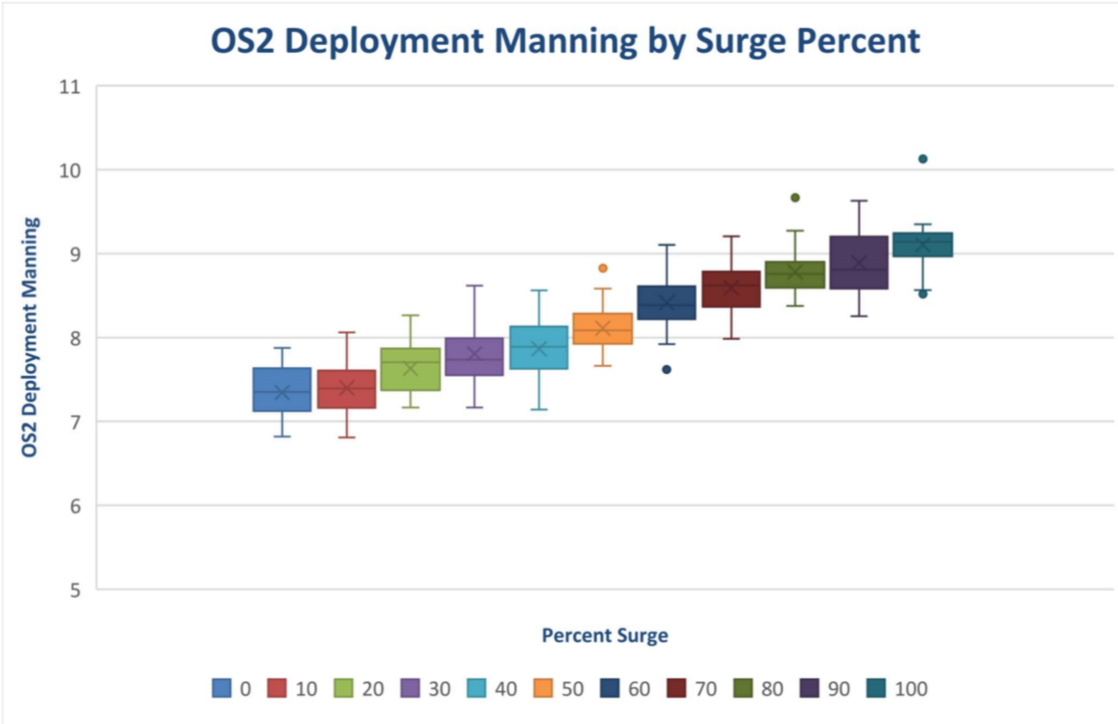

Figure 4.2. Deployment Manning Levels for Increasing Surge Percent

expect a higher manning level for deployments when this effect is accounted for. Appendix B describes an optimization model that can be used to demonstrate further improved manning levels for a given surge utilization percent.

Only OS2s are discussed here because Sailors are assigned to the surge command only once and the surge assignment tends to happen earlier in Sailors' careers. This is due partially to model design and simplifications, and partially to the amount of time a typical OS Sailor spends as an OS2. If Sailors were eligible for assignment to the surge command more than once per career, OS1 and OSC deployment manning would also be expected to increase.

4.2 Proof of Concept

As a POC, the model was designed to demonstrate whether manning can be improved on deployments by removing authorized billets from ships that are not deployed and using those billets to establish a surge command. Aside from improved deployment manning, we expect to see decreased manning on non-deployed ships, thereby decreasing Sailor under-utilization. Figure 4.3 shows the changes in manning on deployed ships as compared to ships available for deployment, but not deployed, and to ships not available to deploy.

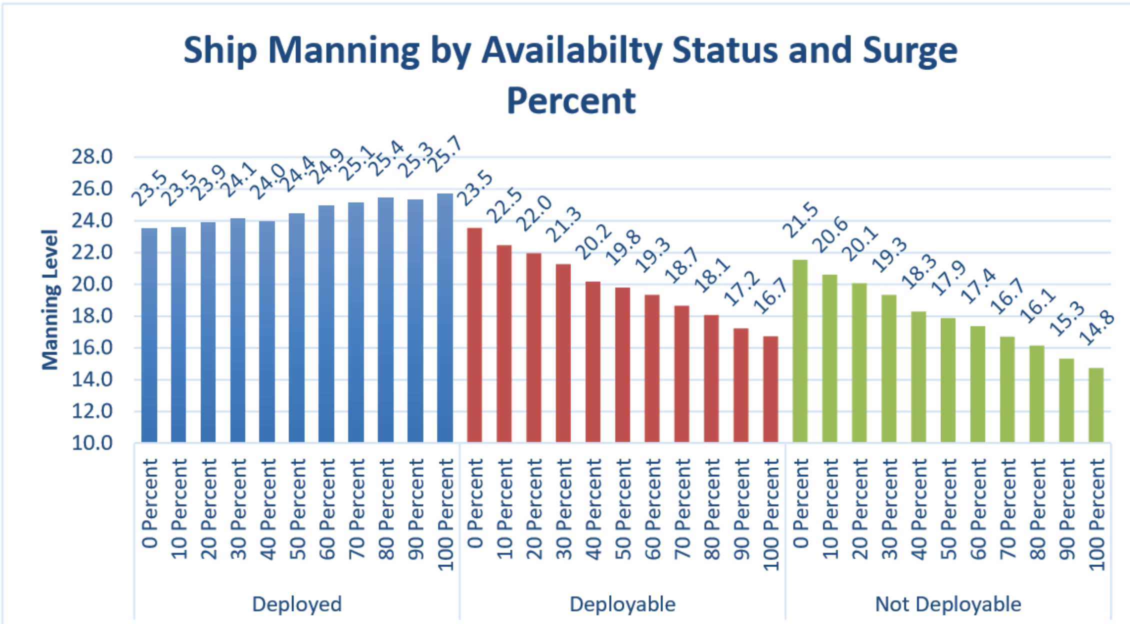

Figure 4.3. Distribution of Sailors as Surge Percent Increases

While deployed ships gain only about two Sailors per deployment, both the deployable and not deployable ships decrease manning by an average of seven Sailors per ship. With an average of 45 ships in port, that equates to an average of 315 Sailors who are not being underutilized. Rather, they are utilizing their time efficiently by contributing to their expected two deployments, then moving along in their sea/shore rotation. For the Sailors assigned to the in-port ships, the little work they have to accomplish is spread between fewer people, thus increasing their utilization.

The fleet movement model successfully demonstrates that the concept of a surge command can be used to improve both Sailor utilization and deployment manning without negatively impacting the Sailors' career progression or increasing the amount of time they would otherwise expect to spend at sea.

CHAPTER 5:
Discussion

Chapter 5 expands on the implications of the results of the POC and proposed future work to be done in order to fully understand the possible impact of instituting a surge command.

5.1 Discussion

As a successful POC, the DES and this thesis have demonstrated improved manning and Sailor utilization. What was not included in the model, but is undoubtedly related to manning levels and Sailor utilization are quality of life, promotability, and the effect on reenlistment decisions. The model assumes Sailors exit the Navy and promote according to the the current trends. However, the current trends are a result of how many Sailors elect OS as their rate and how many Sailors choose to reenlist after their initial commitment.

Many OS accessions are Sailors who join the Navy without a specified rate (i.e., undesignated striker), then work on a ship for a while to learn about the different rates available (Settles 2020) before choosing one of which they will remain for the rest of their career. It is easy to observe, when stationed aboard a ship, that the OSs spend most of their in-port time cleaning and most of their underway time standing a port-and-starboard watch schedule. This observation is likely to affect the decision of undesignated striker Sailors when choosing their future rate. If the workload imbalance is corrected, it is possible that the OS community would access more junior Sailors, which would increase the manning level of OS3 Sailors from the current level of 71.6% (NPC 2019).

Furthermore, when a Sailor's time is better utilized, their skills stay fresh, their deployment schedules remain relatively predictable, and they gain more say in the geographic locations to which they are assigned (all of which are accomplished by use of a surge command). As a result, junior Sailors are more likely to view their Navy experience and their job positively, which will likely improve not only the quality of their work and safety standards (Hebb 1955; Game 2007), but also their propensity to reenlist. Improved reenlistment rates following the initial commitment would improve OS2 manning from the current level of 90.4%.

With improved accessions and increased reenlistments, the manning level of deployed ships would continue to improve beyond what is demonstrated by this thesis. With improved manning on ships, there would be less need for incentive programs like SDIP and high bonuses for reenlistment. By eliminating SDIP eligibility for OSs , the Navy would save nearly half a million dollars a year. Lowering reenlistment bonus amounts would increase the savings.

5.2 Future Work

Following a successful POC, it is prudent to conduct more studies with fewer simplifications and more details prior to moving forward with the proposed idea. To that end, there is much more work that can be done to determine the feasibility and practicality of implementing a surge command.

The model of a ship's status (available to deploy or not available to deploy) can be refined to include periods of pre-deployment workups and special assignment missions. These details would allow surge Sailors to be used for smaller missions, thereby giving more details regarding how many Sailors are needed at the surge command in order to adequately support deployments.

Other ship classes can be included in the model to give a more realistic picture of the fleet-wide effects of a surge command. DDG-51 class Destroyers make up only a fraction of the total fleet, so including other platforms would allow more Sailors to be eligible for the surge command. However, there would also be more ships deploying. This could cause changes to the positive results of this POC.

This model does not differentiate between Sailors who have critical NECs and those who do not, so it does not provide an accurate look at the effects on manning of critical skills for deployments. Modifying the model to include NECs will provide a more thorough understanding of the effects of a surge command on critical skill manning levels. It will also allow for modeling an increase of Sailors who attain the critical NECs as the quality of life improves for Sailors with those NECs (i.e., improved deployment manning).

When a Sailor spends more time performing their skill-specific duties, they are better prepared for advancement exams. Therefore, the model could shorten the time in grade for

Sailors who are assigned to the surge command. This would provide a more realistic view of the distribution of Sailors by rank on deployments and throughout the fleet. Similarly, the model can increase time-in-service for Sailors who are assigned to the surge command and advance sooner. Improved workload balance and earlier promotion are both likely to improve reenlistment rates.

Finally, in order to fully understand the possible impact of a surge command, other rates can be modelled. While OSs are an extreme example of workload imbalance, there are other rates that could benefit from a more even distribution of work throughout the ship's availability cycle.

Aside from expanding the DES model, future work should include Sailor interviews to better understand the impact of workload balance on quality of life and the subsequent impact on rate-selection and reenlistment decisions. In addition, the optimization model in Appendix B can be used to better understand the improvements that come from inclusion of a detailer when deciding to which ship a Sailor should be assigned.

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APPENDIX A: Interpreting Event Graphs

Schruben and Schruben (2009) describe how to interpret the edges (lines) and vertices (circles) of event graphs. Figure A.1 shows two events, A and B, with an edge from A to B. It depicts that when event A occurs, it may cause event B to occur. If condition (i) is met, then event B will be scheduled with a time-delay of t. Neither (i) nor t are required components of any connected events. However, if they are shown on the event graph, their default values are used, “true” and 0.0, respectively.

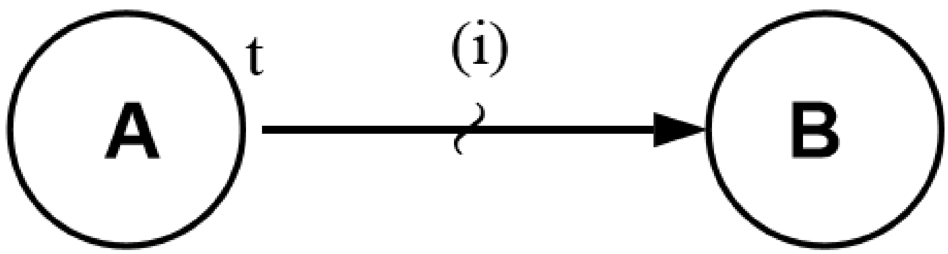

Figure A.1. Simple Event Graph. Source: Schruben and Schruben (2009).

Figure A.2 is an example of an event graph with entities, as described by Buss (2019). It models an arrival process in which a Run event initiates the system to have an empty queue q and k available servers (S). When a customer entity c arrives, it is added to the queue (q) and its arrival time is stored as an attribute. If a server is available (S>0), the customer (c) will be scheduled to start service immediately. At the start of service, the number of available servers (S) will decrease by 1, the customer (c) will be removed from the queue (q), and the end of service for customer (c) will be scheduled with a time delay of t_s. The start service event also determines how much time has elapsed since the customer (c) arrived in the system (D). This is an attribute of customer (c), which references the arrival time to calculate the elapsed time. When end service is executed, the total time in system (W) is calculated again using the arrival time attribute of the customer (c). The end service event also adds a server back to the list of available servers (S), and, if the queue is not empty (q>0), a start service event will be immediately scheduled.

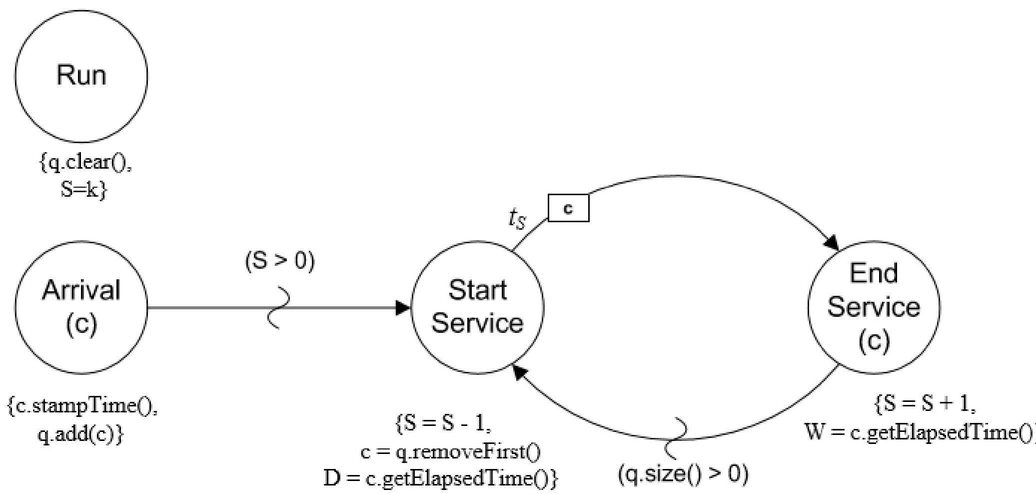

Figure A.2. Simple Event Graph with Entities. Source: Buss (2019).

APPENDIX B: Optimization Model

This optimization model is designed to be used with the data obtained from this thesis's DES model. The parameters and constraints align with those in the DES, and the objective function mimics the reward value calculated in the DES. However, the optimization is simplified further to remove rank from the Sailors. This makes the optimization an imperfect representation of the improvements possible over the DES model, but the optimization constraints are believed to provide enough restriction to make the results valid and useful.

The parameters should be set to limit each Sailor to the same time in service as they would be stochastically assigned in the DES model, and to serve the same number of tours throughout their career as they would in the DES model, including if and when they are assigned to the surge command. Each ship should start and end deployments at the times they would according to the DES model. The constraints will then determine the best ship assignment for each Sailor for each of their sea tours in order to maximize deployment manning. The reward value will be directly comparable to the reward value from the DES model, and is an indication of how having a human-in-the-loop (i.e., a detailer) can further improve deployment manning levels.

Indices and Sets:

$s \in \mathcal{S} = \{1,2,3,\ldots,S\}$: sailors

$t \in \mathcal{T} = \{1,2,3,\ldots,T\}$: tours

$p \in \mathcal{P} = \{1,2,3,\ldots,P\}$: ships

$l \in \mathcal{L} = \{1,2,3,\ldots,L\}$: staffing levels for each deployment

$d, d' \in \mathcal{D} = \{1,2,3,\ldots,D\}$: deployments

$(d, p) \in \mathcal{SHIP} \subseteq \mathcal{D} \times \mathcal{P}$: deployment d is on ship p

$(d, d') \in \mathcal{EXC} \subseteq \mathcal{D} \times \mathcal{D}$: a sailor cannot be assigned to both deployment d and deployment d'

$t \in \mathcal{SEA} \subseteq \mathcal{T}$: tour t is a sea tour

$t \in \mathcal{SHORE} \subseteq \mathcal{T}$: tour t is a shore tour

$(s,t) \in \mathcal{SQ} \subseteq \mathcal{S} \times \mathcal{T}$: tour t is a status quo command sea tour for sailor s

$(s,t) \in \mathcal{ALL} \subseteq \mathcal{S} \times \mathcal{T}$: tour t is tour for sailor s

$(s,t) \in \mathcal{FIRST} \subseteq \mathcal{S} \times \mathcal{T}$: tour t is the first tour for sailor s

$(s,t) \in \mathcal{LAST} \subseteq \mathcal{S} \times \mathcal{T}$: tour t is the last tour for sailor s

$(s,d) \in \mathcal{CANDO} \subseteq \mathcal{S} \times \mathcal{D}$: deployment d occurs while sailor s is in service

Parameters:

$staff_l \in \mathbb{Z}_+$: number of sailors at staffing level $l \in \mathcal{L}$

$reward_{d,l} \in \mathbb{R}_+$: marginal reward for staffing deployment $d \in \mathcal{D}$ at at least level $l \in \mathcal{L}$

$depstart_d \in \mathbb{R}_+$: start time of deployment $d \in \mathcal{D}$

$depend_d \in \mathbb{R}_+$: end time of deployment $d \in \mathcal{D}$

$onduty_s \in \mathbb{R}_+$: start time of sailor $s \in \mathcal{S}$'s first tour

$offduty_s \in \mathbb{R}_+$: end time of sailor $s \in \mathcal{S}$'s last tour

$minlength_{s,t} \in \mathbb{R}_+$: minimum duration of tour $t \in \mathcal{T}$ for sailor $s \in \mathcal{S}$

$maxlength_{s,t} \in \mathbb{R}_+$: maximum duration of tour $t \in \mathcal{T}$ for sailor $s \in \mathcal{S}$

Nonnegative Decision Variables:

$START_{s,t}$: start time of tour $t \in \mathcal{T}$ for sailor $s \in \mathcal{S}$

Binary Decision Variables:

$A_{s,p,t}$: =1 if sailor $s \in \mathcal{S}$ serves on ship $p \in \mathcal{P}$ in status quo tour $t \in \mathcal{T}$, 0 otherwise

$B_{d,l}$: =1 if deployment $d \in \mathcal{D}$ is assigned at least $staff_l$ sailors, 0 otherwise

$Y_{s,d,t}$: =1 if sailor $s \in \mathcal{S}$ serves in deployment $d \in \mathcal{D}$ in tour $t \in \mathcal{T}$, 0 otherwise

Objective Function:

$$\min z = \sum_{d \in \mathcal{D}} \sum_{l \in \mathcal{L}} reward_{d,l} \, B_{d,l}$$

Constraints:

$START_{s,t=1} = onduty_s \quad \forall s \in \mathcal{S}, t \in \mathcal{T} : (s,t) \in \mathcal{FIRST}$: each sailor begins his or her first tour at the appropriate time

$START_{s,t} \geq START_{s,t-1} + minlength_{s,t-1} \quad \forall s \in \mathcal{S}, t > 1 : (s,t) \in \mathcal{ALL}, (s,t) \notin \mathcal{LAST}$: each tour is at least its minimum length

$START_{s,t} \leq START_{s,t-1} + maxlength_{s,t-1} \quad \forall s \in \mathcal{S}, t > 1 : (s,t) \in \mathcal{ALL}, (s,t) \notin \mathcal{LAST}$: $eachtourisatmostitsmaximumlength$

$START_{s,t=T} \geq offduty_s - maxlength_{s,t=T} \quad \forall s \in \mathcal{S}, t \in \mathcal{T} : (s,t) \in \mathcal{LAST}$: sailor s's last tour must be of an appropriate length

$START_{s,t=T} \leq offduty_s - minlength_{s,t=T} \quad \forall s \in \mathcal{S}, t \in \mathcal{T} : (s,t) \in \mathcal{LAST}$: sailor s's last tour must be of an appropriate length

$START_{s,t} \leq depstart_d Y_{s,d,t} + (onduty_s + \sum_{t'<t} maxlength_{s,t'})(1 - Y_{s,d,t}) \quad \forall s \in \mathcal{S}, d \in \mathcal{D}, t \in \mathcal{SEA} : (s,d) \in \mathcal{CANDO}, (s,t) \in \mathcal{ALL}$: if sailor s is assigned to deployment d in tour t, the deployment's start time must occur during the tour

$START_{s,t+1} \geq depend_d Y_{s,d,t} \quad \forall s \in \mathcal{S}, d \in \mathcal{D}, t < T : t \in \mathcal{SEA}, (s,t) \in \mathcal{CANDO}, (s,t+1) \in \mathcal{ALL}$: if sailor s is assigned to deployment d in tour t, the deployment's end time must occur during the tour

$\sum_{t \in \mathcal{SEA}} Y_{s,d,t} + \sum_{t \in \mathcal{SEA}} Y_{s,d',t} \leq 1 \quad \forall s \in \mathcal{S}, (d,d') \in \mathcal{EXC} : (s,d) \in \mathcal{CANDO}, (s,d') \in \mathcal{CANDO}$: sailor s cannot do two mutually exclusive deployments

$B_{d,l} \leq \frac{\sum_{s \in \mathcal{S}} \sum_{t \in \mathcal{SEA}} Y_{s,d,t}}{staff_l} \quad \forall d \in \mathcal{D}, l \in \mathcal{L}$: deployment d must have at least $staff_l$ sailors assigned in order to accrue the appropriate marginal reward

$Y_{s,d,t} \leq A_{s,p,t} \quad \forall (d,p) \in \mathcal{SHIP}, (s,t) \in \mathcal{SQ} : (s,d) \in \mathcal{CANDO}$: sailor s cannot participate in deployments on ship p during status quo tour t unless he or she is assigned to ship p

$\sum_{p \in \mathcal{P}} A_{s,p,t} = 1 \quad \forall (s,t) \in \mathcal{SQ}$: sailor s is assigned to a ship in each status quo sea tour

$A_{s,p,t} = 0 \quad \forall s \in \mathcal{S}, t \notin \mathcal{SEA}, p \in \mathcal{P}$: sailor s is not assigned to a ship in any shore tour

$A_{s,p,t} \in \{0,1\} \quad \forall s,p,t$: define decision variable domains

$B_{d,l} \in \{0,1\} \quad \forall d,l$: define decision variable domains

$Y_{s,d,t} \in \{0, 1\} \quad \forall s, d, t$: define decision variable domains

$START_{s,t} \geq 0 \quad \forall s, t$: define decision variable domains

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