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THESIS

**EVALUATION OF MARINE CORPS MANPOWER
COMPUTER SIMULATION MODEL**

by

Eric S. Anderson

December 2016

Thesis Advisor:	Arnold Buss
Second Reader:	Neil Rowe

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13. ABSTRACT (maximum 200 words)

Marine Corps Manpower Plans and Policy Division, Manpower & Reserve Affairs, is responsible for formulating Marine Corps force manpower plans. Accomplishing this mission requires extensive knowledge of the Human Resource Development Process (HRDP) for controlling future personnel attrition, retention, and accession quantities to ensure appropriate quantities of its various Military Occupational Specialties (MOS) and overall end strength are maintained. To assist their mission, an agent-based computer simulation model was developed in the Java computer language. This thesis investigates that simulation model, titled Manpower Simulation Model (MSM). This thesis provides documentation of MSM's architecture and processes, tests the sensitivity of its inputs through the use of an experimental design, and validates MSM's output measures by calculating the relative error for five successive forecast years for various HRDP categories. This thesis found that MSM's structure and output measurement responses aligned with HRDP practices. With respect to validation, on average the HRDP categories losses and accessions underestimated by 17 and 18 percent, respectively, while gains overestimated by 36 percent. The category promotions generally underestimated, but lessened in magnitude as grade increased. The category retention consistently overestimated for all grades. Lastly, the MSM showed biasness toward retaining Marines over backfilling vacancies through accessions.

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EVALUATION OF MARINE CORPS MANPOWER COMPUTER SIMULATION MODEL

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Submitted in partial fulfillment of the
requirements for the degree of

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Marine Corps Manpower Plans and Policy Division, Manpower & Reserve Affairs, is responsible for formulating Marine Corps force manpower plans. Accomplishing this mission requires extensive knowledge of the Human Resource Development Process (HRDP) for controlling future personnel attrition, retention, and accession quantities to ensure appropriate quantities of its various Military Occupational Specialties (MOS) and overall end strength are maintained. To assist their mission, an agent-based computer simulation model was developed in the Java computer language. This thesis investigates that simulation model, titled Manpower Simulation Model (MSM). This thesis provides documentation of MSM's architecture and processes, tests the sensitivity of its inputs through the use of an experimental design, and validates MSM's output measures by calculating the relative error for five successive forecast years for various HRDP categories. This thesis found that MSM's structure and output measurement responses aligned with HRDP practices. With respect to validation, on average the HRDP categories losses and accessions underestimated by 17 and 18 percent, respectively, while gains overestimated by 36 percent. The category promotions generally underestimated, but lessened in magnitude as grade increased. The category retention consistently overestimated for all grades. Lastly, the MSM showed biasness toward retaining Marines over backfilling vacancies through accessions.

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LIST OF ACRONYMS AND ABBREVIATIONS

API	application program interface
ASR	authorized strength report
BMOS	secondary military occupational specialty
CMC	Commandant of the Marine Corps
DC CD&I	Deputy Commandant Combat Development and Integration
DOE	design of experiments
DOPMA	Defense Officer Personnel Management Act
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Policy
EAD	extended active duty
EAS	end of active service
E2O	enlisted to officer
ECC	expiration of current contract
ECFC	Enlisted Career Force Controls
ESGM	Enlisted Staffing Goal Model
FTAP	First Term Alignment Plan
FY	fiscal year
GAR	Grade Adjusted Recapitulation
gainCat	gain category
HRDP	human resources development process
Lat	lateral
M&RA	Manpower & Reserve Affairs
max	maximum
MCO	Marine Corps Order
MM	Manpower Management Division
MP	Manpower Plans and Policy Division
MOS	military occupational specialty
MSM	Manpower Simulation Model
NOLH	Nearly Orthogonal Latin Hypercube
occField	occupational specialty field

ODSE	Operational Data Store Enterprise
OSGM	Officer Staffing Goal Model
P2T2	patients, prisoners, transients, and trainees
PMOS	Primary military occupational specialty
ret	retired
RNG	Random number Generator
SRENL	senior reenlisted
STAP	Subsequent Term Alignment Plan
T/O	Table of Organization
TFDW	Total Force Data Warehouse
TFSMS	Total Force Structure Management System
TIG	time in grade
TIS	time in service
UIC	unit identification code
YOS	years of service

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I.   INTRODUCTION

A.   BACKGROUND

The Marine Corps is regarded as being the Nation's premier expeditionary force in readiness. Before it can ever be deployed to conduct its various ranges of military operations, it must ensure it has the proper personnel in place to execute those missions. Annotated as the Human Resources Development Process (HRDP), the Marines and civilians at Manpower and Reserve Affairs (M&RA) wrestle with this convoluted and mission critical process to ensure the Marine Corps has the proper number of Marines proportionately allocated across its various Military Occupations Specialties (MOS). To add an additional layer of difficultly, M&RA must accomplish this mission for an organization that has an extreme flux in personnel change.

Averaging from the past decade, each year there are approximately 30,000 Marines that choose to enter and exit the Marine Corps (Spafford, 2016). Roughly 60% of Marines are on their first enlistment contract, 45% are below the paygrade of E-4, and 75% will not reenlist for a second contract (Spafford, 2016). Figure 1 shows this dramatic manpower drop of Enlisted Marines exiting the Marine Corps after their first enlistment contract. This significant drop is due to the general manpower structure of the Marine Corps, as well as its merit-based promotion selection that is in conjunction with the "up or out" manpower system. To ensure mission accomplishment within M&RA, it is crucial to understand these factors that drive manpower movements. The manpower process is expanded on in Section C or this chapter.
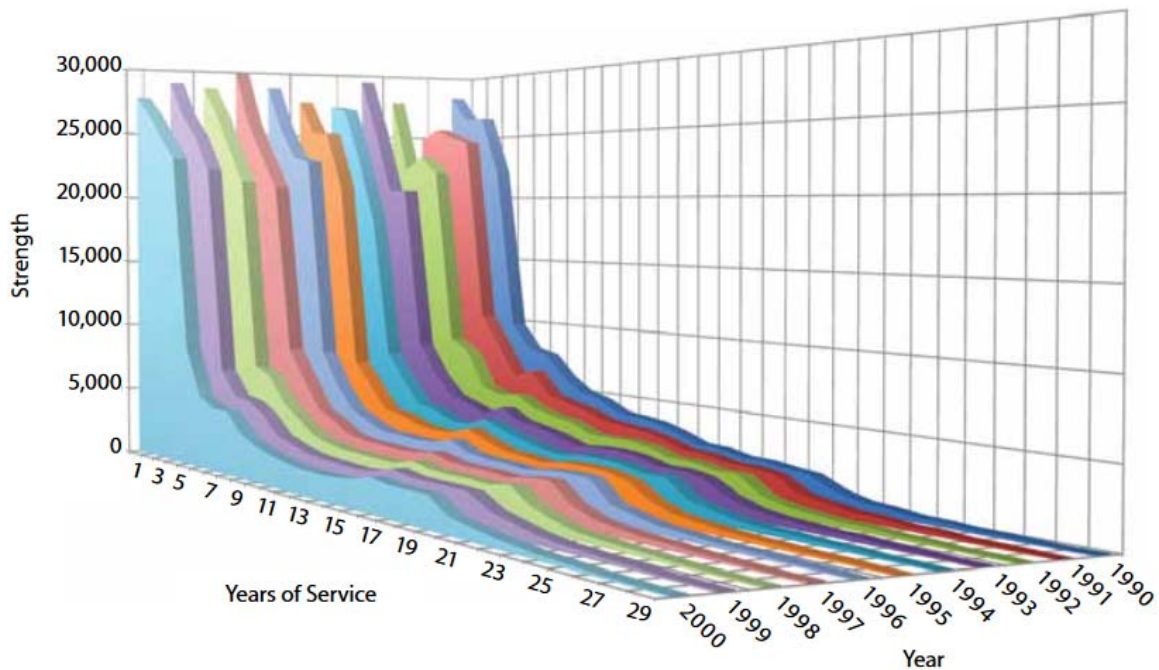
Figure 1. Marine Corps Enlisted Force Fiscal Year (FY) 1990–2000.
Source: Rostker (2013).

Advances in technology have facilitated the ability to develop tools that yield enhanced manpower analysis. However, most of these decision making tools are still relatively isolated models that provide insightful information in a narrow spectrum of the HRDP (R. A. Garrick, personal communication, April 6, 2016). Naturally, policy and procedures implemented within M&RA try to mitigate the unintended consequences and errors of assembling the various patches of information. To bridge this gap, the power of computer simulation was explored with the intent to integrate the numerous processes of HRDP into a single simulation model.

The first documented computer modeling software that attempted to provide a HRDP whole-system oriented viewpoint was an Arena model. Created by Rockwell Automation, Arena is a simulation software that models business practices to assist that business in its "ability to analyze and make decisions on how to improve (their) process" (Rockwell Automation, 2016). Used at M&RA from roughly 2008 to 2011, this model was cumbersome, slow, and complex.

Ultimately, its inability to forecast numerous years into the future and undocumented source code methods led this software program to become untrusted, impractical, and unused to the point that its contracting license with Rockwell Automation was not renewed upon its licensing expiration (M. Ramirez, personal communication, April 4, 2016).

In 2011, former Naval Postgraduate School Operations Research graduate Captain Ronald Garrick, USMC (ret), arrived at Manpower Studies and Analysis Branch, M&RA, thereupon noticing the technology capability gap and began developing what ultimately became the Manpower Simulation Model (MSM).

The MSM is a Java language agent-based simulation program that aims to integrate the numerous processes of the HRDP under a single computer simulation model. Using the Marine Corps' force structure as its virtual architecture and manpower shaping rules as its internal constraints, the program combines the deterministic aspects of the HRDP with a stochastic simulation capability that produces a multitude of output metrics. These output metrics aid the decision makers at M&RA to gain insightful forecasted metrics that range across numerous fiscal years, and breaks down into the dimensional analysis at the MOS skill and grade level.

B.   PURPOSE

This thesis provides an overall evaluation of the MSM and its potential for future usage so that its output metrics can be used with trust and confidence in making manpower decisions by the leaders within M&RA. This was accomplished by inspecting and documenting the various internal structures and procedures within the MSM. A software-verification approach was taken to test the sensitivity of its input metrics through the use of an experimental design. Finally, a software-validation approach was used to evaluate the model's accuracy against historical Marine Corps manpower data.

C.   THE MANPOWER PROCESS

To understand the underlying concepts of the MSM, and its goal of providing forecasted metrics, one first has to understand the enlisted HRDP. The intention of this section is to provide the reader with an overview of this process, rather than an in-depth detailed analysis, to serve as the basis for comparison to the MSM. This section will highlight the conjoined process for Officer and Enlisted personnel where appropriate. However, the scope of this thesis is purely focused on enlisted personnel, since that is the personnel parameter used within the MSM.

Forecasting manpower quantities are derived from two critical components; the absolute manpower structure of the Marine Corps and the personnel movement that occurs within it. The first part of this section will focus on manpower structure. Comprising of approximately 240 MOSs that are spread throughout 9 Enlisted grades, the Marine Corps Enlisted Force averages around 162,000 Marines at any given time (Manpower Plans and Policy Division, 2016).

Determining what the force structure should be for a given fiscal year is a cumbersome process. The enlisted force is derived from manpower requirements or previous force structures. These requirements are determined from occupational field (occField) sponsors who are specialized and advocate for occFields to possess specific levels of experience, where experience can be synonymous with a Marine's time in service, that are proportionality distributed across the Marine Corps in terms of both depth and breadth. The sponsor receives guidance from the Commandant of the Marine Corps in his strategic analysis of various documents such as the National Security Strategy and the National Defense Strategy, as well as from current Combatant Commanders who yield bottom-up refinement to previously established force structures (United States Marine Corps, 2009). The Deputy Commandant Combat Development and Integration (DC CD&I) ultimately approves the new requirements list, which appropriately becomes the documented Table of Organization (T/O). Figure 2

depicts this process, as described in Marine Corps Order (MCO) 5311.1D Total Force Structure Process.
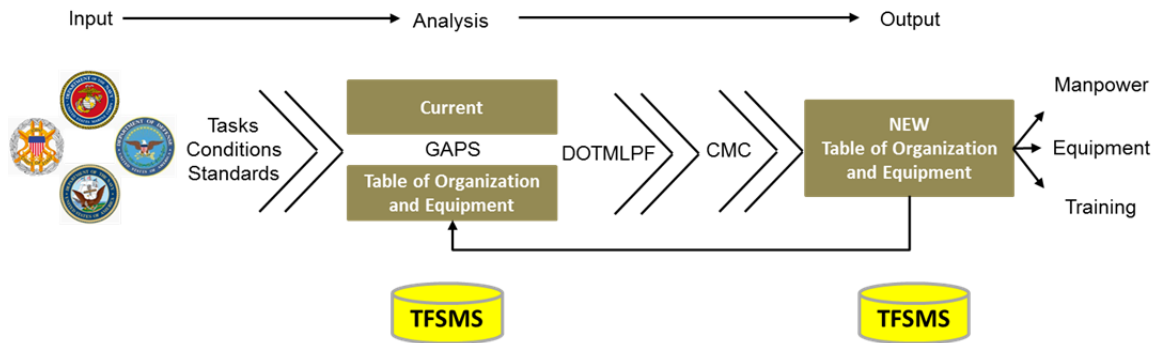
Figure 2. The Marine Corps Total Force Structure Process. Adapted from United States Marine Corps (2009).

The T/O is therefore the foundational document toward which the Marine Corps tries to build and sustain its force, which is accomplished by "buying billet seats." Every purchased billet has political and budgetary constraints associated with it. The process of "buying billet seats" is synonymous with the fiscal year's approved end strength as provided by the National Defense Authorization Act (U.S. Department of Defense, 1996). When differences between what the Marine Corps would like to have, the T/O, and what the Marine Corps is allowed to have, its approved end strength, the Manning and Staffing Precedence Order is taken into account. The Manning and Staffing Precedence Order is a MCO that identifies which units will receive priority in fulfilling billet vacancies, as directed by the Commandant of the Marine Corps (United States Marine Corps, 2012). The combination of these steps in addition to the original T/O produces the Authorized Strength Report (ASR).

The ASR is the principal document that M&RA receives to complete the final components of the HRDP. However, before it can be used it has to be reconciled to be compliant with political and budgetary constraints. For budgetary constraints, the grade quantities are aggregated and summed with respect to that grade's pay to ensure that monetary personnel limits are not exceeded.

Within Manpower Plans and Policy Division (MP), additional manning controls are implemented to account for the Marine Corps' patients, prisoners, transients, and trainees (P2T2). Accounting for P2T2 against the ASR produces the Grade Adjusted Recapitulation (GAR). The manpower metrics specified in the GAR serve as the final manpower targets for a specific fiscal year. A snapshot of the GARs manpower metrics may be viewed in Appendix B. The GAR is the manpower structure document the MSM uses to build its virtual architecture from.

Building off of the absolute structure, personnel movement becomes the second critical component to properly forecasting manpower requirements. This component is often illustrated in a graphic called the Enlisted Manpower Pyramid, shown in Figure 3. It includes external and internal personnel movement, which is classified into four categorical areas: accessions/gains, retentions/reenlistments, promotions, and losses.
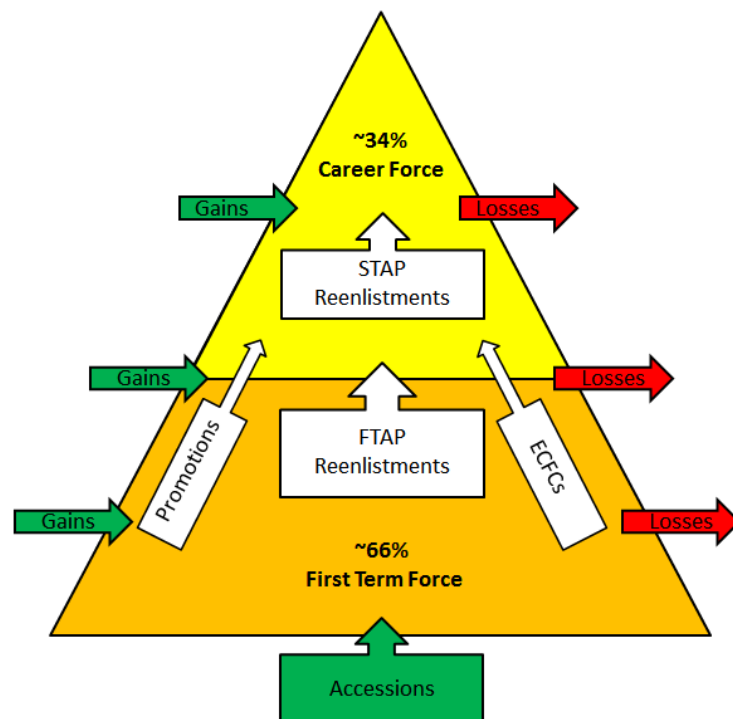
Figure 3. Enlisted Manpower Pyramid. Adapted from Spafford (2016).

These four components yield insight into how Marines are moving through the manpower structure. These four components are further broken down to capture specific manpower movement. For accessions/gains, sub-categories include Marines returning from:

- Medical Holds

- End of Active Service (EAS) Holds

- Deserter Status

- Fulfilling Recruiter Billets

- Cross Year Extensions

- Non-Prior Service Accessions

For retentions/reenlistments, this category is broken down into two sub-categories: First Term Alignment Plan (FTAP) and the Subsequent Term Alignment Plan (STAP). These plans shape the inventory of the enlisted force by controlling the number of enlistments for the respective term force (United States Marine Corps, 2010). These plans are critical as they ensure the proper quantity of MOSs, with respect to grade distribution, are being retained within the Marine Corps.

The component promotions does not have a specific sub-category, however it is proportionally controlled by the Enlisted Career Force Controls (ECFC). ECFC impacts two specific areas, first they impact the promotion zones control parameters. These controls ensure each Marine receives an opportunity to be promoted, as well as ensures a Marine has the proper experience to fulfill higher grade responsibilities. Secondly, the controls facilitate the process of only retaining the most qualified Marines by forcing Marines who fall below acceptable career progression standards out of the service. For example, if Marines are continuously being passed over for promotion it is assumed they do not possess the high-standard qualifications the Marine Corps is looking for and therefore should not continue to be retained within the force (United States Marine Corps, 2010).

The component losses has multiple sub-categories, specifically categorizing Marines that:

- Receive commission and become Officers, referred to as an enlisted to officer (E2O) transition

- Drop out and separate from Boot Camp

- Transition into the reserves

- Reach service limitations

- Retire

- Execute general EAS

- Death cases

- Non-EAS cases

Aggregating and associating the four manpower movement categories yields detailed rates for Marines moving among the manpower structure. Cognizance of these rates allow manpower planners to take today's force, extrapolate the data, and forecast what they believe will be the future's force. Projections are developed at the beginning of each fiscal year to estimate the amount of Marines moving within the manpower pyramid in order to anticipate the quantity of accessions needed to backfill future vacancies. These forecasts allow the Marine Corps to establish milestones that facilitate it to conclude a fiscal year exactly at the National Defense Authorization Act's approved end strength. This is the manpower management game Manpower Plans and Policy Division is continuously playing, and its success is crucial to ensure the Marine Corps' manpower readiness.

II.   TECHNICAL REVIEW

This chapter serves to supply the reader with the technical background knowledge that will facilitate the understanding of MSM's construction. This is not an exhaustive background but rather focuses on the key components that give the MSM its greatest capabilities. Finally, this chapter will conclude with an overview of the scientific methodologies used for the evaluation of the MSM's input and processes sensitivity.

A.   AGENT-BASED MODELING AND SIMULATION

Prior to agent-based simulation modeling, computer models used mathematical formulas to compute statistics of interest (Railsback & Grimm, 2012). As object oriented computer languages have impacted computer programming, its methodology has also impacted modeling and the ability to track objects, annotated as agents within simulation, through the system.

"Agent-based modeling are thus models where individual agents are described as unique and autonomous entities that usually interact with each other and their environment locally" (Railsback & Grimm, 2012, p. 10). Agents are entities that can be constructed to have very specific behaviors. As entities, they are able to retain the statistics of their interaction with the system, which allows for enhanced data analysis. This includes analyzing how the agent is impacted by the rules and processes within the system (Railsback & Grimm, 2012).

This type of problem framing allows for three separate aspects to be examined: the agent as an individual, agents aggregated to form a group, and the system as a whole. These aspects facilitate the user's ability to examine the model and the total throughput of an agent within a system, and more importantly gain a further understanding of the third, fourth, even tenth-order consequences associated with an environment policy decision (Railsback & Grimm, 2012).

B.   STATES, EVENTS, AND EVENT GRAPH METHODOLOGY

In modeling and simulation, understanding the throughput of the numerous processes and variables that are adjusted within the simulation can be a daunting task. To simplify these actions and understand the numerous calculations that occur, these processes can be broken down into a few graphic illustrations. For a majority of simulations, to include the MSM, the two predominant graphic illustrations are state variables and events.

A state variable is a variable that "has a possibility of changing value at least once during any given simulation run" (Buss, 2011, p. 1-1). These items provide the user with a snapshot description of the system at any specific point in time. Over the course of a simulation, state variables are identified as being piecewise constants. This means that a state variable can only change its value instantaneously at a specified trigger point. These trigger points can be continuous time steps, which is the method of advancement for the MSM, or at previously specified non-continuous discrete times. This capability for a state to change, to transition to a new state, introduces the constraint called an event (Buss, 2011).

An event is a particular action that occurs within a simulation, and its occurrence is the trigger for a state variable to change its value instantaneously. Events can be mapped to change a plethora of state variables in a singular instance, or as little as none. The key take away is that no state variable is allowed to change its value without being initiated to do so by the instance of an event (Buss, 2011).

Various practices have been developed to illustrate these state variables and event interactions; one such practice used is the event graph. An event graph is an illustration that depicts states, the possible transitions that a state can execute, the state variables that are required to be updated with the execution of that event, and any constraints that are emplaced for the event to occur. The aggregation of these illustrations describes a particular process within the model;

and is captured by an event graph (Buss, 2011). Figure 4 is an event graph that depicts a specific process; in the case of this example a Multiple Server Queue process. The figure is annotated with numerous descriptions to identify the various components of an event graph. Dotted red arrows link these annotations to their respective event graph illustrations.
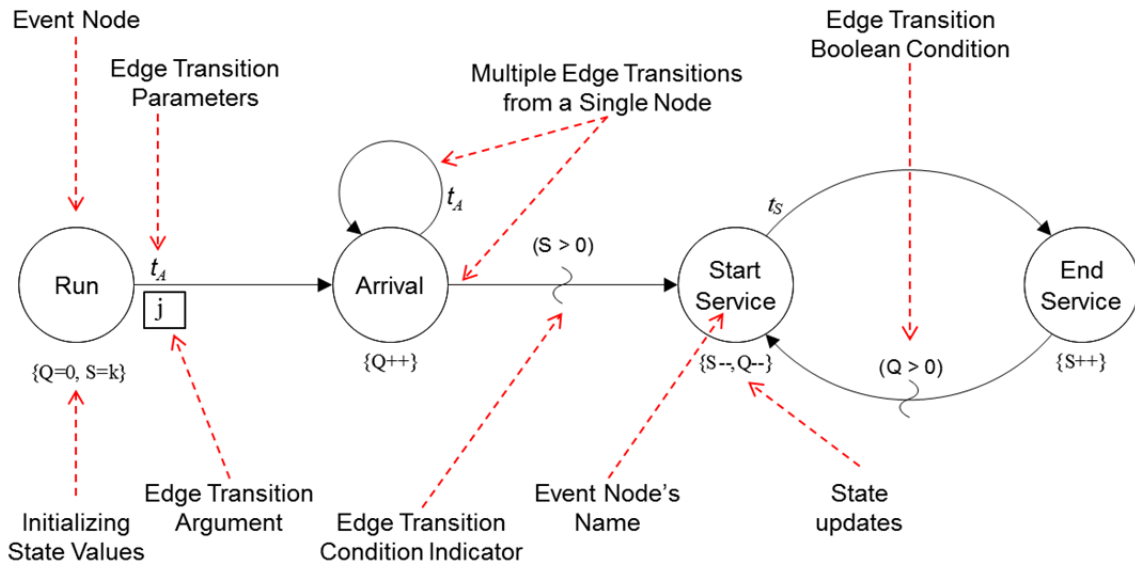
Figure 4. Multiple Server Queue Event Graph with Legend.
Adapted from Buss (2011).

Within an event graph, each event is represented by its annotated circle, called a node. Directly under the node, the states that are to be updated by the execution of that particular event are represented in equation form. Connecting nodes to each other is accomplished by a one-way arrow, commonly referred to as an edge. Because this edge implicates a transition that can only occur in one specific direction, this graph is a directed graph. Resting in the middle of the edges are the conditional statements that serve as requirements that constrain the next possible event from occurring. These conditions are represented in Boolean form; they are either true and allow the transition to occur or they are false and disallow it. Located at the beginning of each edge are any parameters and arguments that are passed to the next event to specify how it will be

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executed. These parameters and arguments can serve as metric references that affect how certain state functions are executed, or they can serve as dimensional parameters that are used to reference specific states in the state transition formulas (Buss, 2011).

Within the context of the MSM, event graphs become extremely useful in understanding its numerous processes executed. Specifically, they facilitate the ability to easily view the process's logic, and compare it to actual Marine Corps practices. Chapter III documents the structure and main processes within the MSM. Specific MSM event graphs can be found there.

C.   RANDOM NUMBER GENERATORS

The Marine Corps manpower throughput process, the HRDP, is fundamentally built off of the individual Marine. As such, while the HRDP is a discrete process it naturally must account for the human psychological factors that influence every Marine. The Marine Corp's Doctrinal Publication 1, Warfighting, identifies human factors as the intangible dimension of warfare and is the root cause of "complexities, inconsistencies, and peculiarities" that shape war (MCDP-1, 1997). With respect to manpower, this is most notably their free will and the affordability to make decisions that affect their career. These human factors can influence a Marine's decision to reenlist or execute an EAS discharge, continue within their MOS or lateral move into a new MOS, or in the rare case decide to desert the service. Human factors are also present at other key HRDP events. Take for example a promotion board, while the general intent is to promote the most qualified Marines, the promotion selection is always subject to the human factors of the board and their collaborative decision making process. One method to account for the selection and execution of non-deterministic events is to incorporate randomness into a simulation model (Sanchez, 2007).

Within the MSM, a Mersenne Twister random number generator is used to invoke instances of randomness during the HRDP. Once invoked, the randomly

generated number is compared to an event likelihood, which is referenced from a database, to determine if the event's hypothesis is executed (Garrick, 2014). This usage of a random number generator gives the MSM its stochastic modeling feature. Stochastic, in terms of modeling and simulation, can be defined as when "the same set of simulation inputs may produce different outputs" (Sanchez & Wan, 2012, p. 2).

The Mersenne Twister was invented in 1997 by Makoto Matsumoto and Takuji Nishimura. It employs $2^{19937-1}$ iterative possibilities that spread across 623 dimensions, when using a 32-bit computer operating system (Tia & Benkrid, 2009). The Mersenne Twister is an incredibly effective random number generator and has become the most widely used random number generator in modeling and simulation (Tia & Benkrid, 2009).

Stochastic Modeling provides additional analytic capabilities to the user. Unlike deterministic models that yield consistent point output measurements, a stochastic model will distribute those measurements over a range. This distribution allows for the mean and standard deviation of an output measurement to be calculated, which in turn can be derived into likelihood. However, in order to produce an effective distribution of output measurements the model must be repeated multiple times (Law & Kelton, 2000). Further information regarding the implementation and usage of random number generators within the MSM can be found in Chapter III.

D. DESIGN OF EXPERIMENTS

Design of Experiments (DOE) is a statistical approach in conducting experiments to yield information about the processes of a model and how its outputs respond to changes in the inputs. The information produced from these experiments can identify minimum and maximum thresholds for inputs, capture how inputs drive the model to produce its output measurements, as well as understand how policies, codified as processes within the model, affect the model's output measurements (Sanchez & Wan, 2012). History has naturally

utilized DOE within the agriculture industry; seen countless times in the simple scenario of a farmer trying two different fertilizes on his crops to identify which produces the best crop yield. With the aid of computer simulation, DOE's capabilities have expanded to examine and evaluate complex system models before they are ever implemented into the physical world (Sanchez & Wan, 2012).

Specific terminology and nomenclature are used to codify critical parts and processes of a DOE. The inputs of a system that are to be strategically altered per simulation trial are called factors. The number of values a factor can be simulated at, also referred as the discrete range of values for a specific factor, is annotated as levels. The interaction between the varying input factors and the model's output measures is annotated as the model's response surface. Lastly, a trial instance of the various factors set at specific levels is called a design point (Sanchez & Wan, 2012).

Response surfaces can be expressed mathematically, which in turn can be shown as a graphical illustration. These expressions are called metamodels and link how the various input factors impact the model's output measures. How input factors effect a model's response surface can be measured by observing two different impact methods: those that show solely main effects and those that show main effects with additional quadratic effects (Sanchez & Wan, 2012). Main effects are regarded as factors that independently impact the models outputs. Specifically, these are the effects captured when a singular factor is altered. Quadratic effects reveal how factors impact themselves quadratically, as well as how factors interact with other factors in two-way interactions. Equations (1) and (2) show the formula representation for main-effects and quadratic-effects, respectively (Sanchez & Wan, 2012).

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \varepsilon$$

(1)

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{i,j}\left(X_i - \bar{X}_i\right)^2 + \sum_{i=1}^{k-1}\sum_{j=l+1}^{k} \beta_{i,j}\left(X_i - \bar{X}_i\right)\left(X_j - \bar{X}_j\right) + \varepsilon$$

(2)

The final aspect to DOE is the design itself, which defines how the factors will be altered per design point for the entirety of the DOE experiment. By varying these factors in a strategic way the design can simulate the model over the range of possible inputs, called the sample space (Sanchez & Wan, 2012).

Using DOE's previous employment in agriculture to illustrate this idea of a design, let us create the case study to examine under what conditions will produce the greatest crop yield for a farmer. In this experiment, three factors are chosen to be varied; seed type, fertilizer type, and pesticide type. Each factor has two types of brands that will be used; these are the levels for those factors. Listing out every possible configuration yields eight design points for the DOE experiment. This type of design is called a full factorial design with three factors altered at two levels; it is annotated as 2^3. Designs can be illustrated graphically or annotated in matrix form to identify the range of possibilities, the sample space, that the factors of a DOE can assume (Sanchez & Wan, 2012). Figure 5 shows a 2^3 factorial design in matrix and graphical form. Graphical images are great for viewing the sample space and observing how the design points fill it.

Design Point	Term						
	1	2	3	1,2	1,3	2,3	1,2,3
1	−1	−1	−1	+1	+1	+1	−1
2	+1	−1	−1	−1	−1	+1	+1
3	−1	+1	−1	−1	+1	−1	+1
4	+1	+1	−1	+1	−1	−1	−1
5	−1	−1	+1	+1	−1	−1	+1
6	+1	−1	+1	−1	+1	−1	−1
7	−1	+1	+1	−1	−1	+1	−1
8	+1	+1	+1	+1	+1	+1	+1
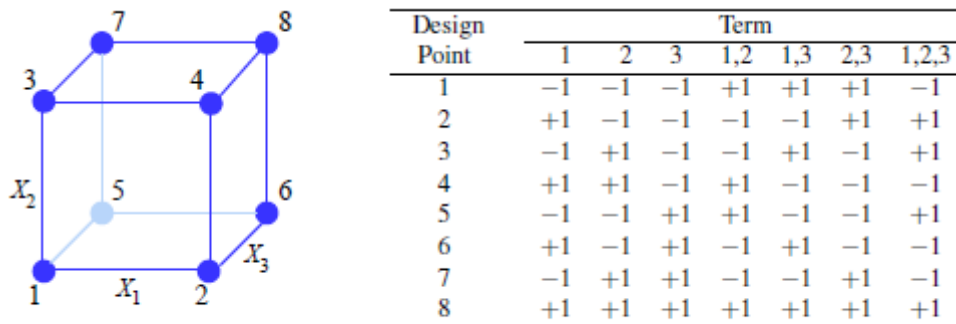
Figure 5. 2^3 Factorial design, graphically and in matrix form, with numbered design points. Source: Sanchez & Wan (2012).

Filling the sample space with design points introduces the fundamental obstacle that must be overcome with DOE designs. On one side of the problem, a user wants to obtain detailed information of how a model responds to its inputs. However, to obtain a perfect model synopsis a user would need an infinite number of design points, which the computational costs to calculate would be unfathomable. Conversely, to achieve a low computational cost model a user might be sacrificing the level of detail the model's response surface yields.

To illustrate this problem better, let's use the children's game capture the flag. In this game, there are two factors that can be used to evaluate how good a child is at playing the game; they are stealth and speed. If the factors are restricted to only two levels, the sample space is left fairly open and a child can only be categorized into extreme stealth-speed options. However, when additionally levels are examined per factor the experimental space is filled with more stealth-speed possibilities. This leaves the user with more possibilities to classify players, and therefore better identify the specific factor levels where the best players resides (Sanchez & Wan, 2012). This effect is illustrated in Figure 6.
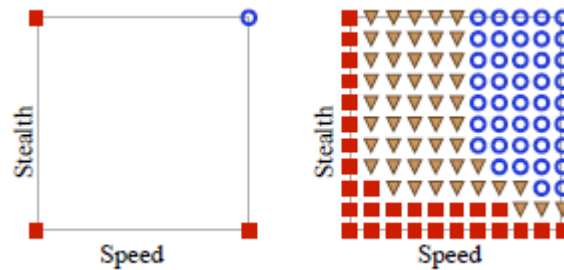
Figure 6. 2^2 and 11^2 Factorial Designs for Capture-the-Flag. Source: Sanchez & Wan (2012).

As seen in Figure 6, being able to better fill the design's experimental space with design points yields substantially more information about a system. This technique is called space-filling (Sanchez & Wan, 2012). However, while it provides detailed information of a model's response surface it is extremely

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computationally expensive to run through all of the specific calculations. Comparing Figure 6's two DOE designs, the 2^2 factorial design requires four simulation runs where the 11^2 factorial design requires 121 simulation runs. One solution to lower computational costs while acquiring detailed information of a model is through the use of a Nearly Orthogonal Latin Hypercube (NOLH) design. A NOLH design accomplishes this by taking a fully filled sample space and strategically selecting design points to run computations on.

Figure 7 depicts this methodical approach pioneered in NOLH designs. Specifically, while only a handful of specific design points were selected from the original 11^2 factorial design, the output measures provided by the response surfaces graph indicate the general areas of peak performance. Additionally, its 11 computations are a full magnitude lower than the 121 computations required in a 11^2 factorial design.
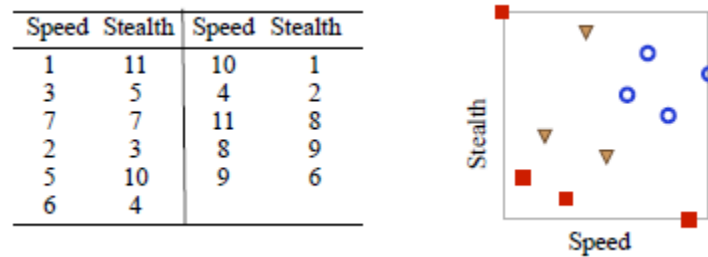
Figure 7. NOLH Example. Source: Sanchez & Wan (2012).

Understanding where design points are being placed within a experimental space is an important part of any DOE design, especially a NOLH. One method to show this layout is through the use of a scatterplot matrix (Sanchez & Wan, 2012). A scatterplot matrix is similar to the two-dimensional graphs shown in Figure 7, but expands off this to include numerous additional dimensions. Figure 8 shows Factorial and NOLH designs and their respective abilities to fill the design space.
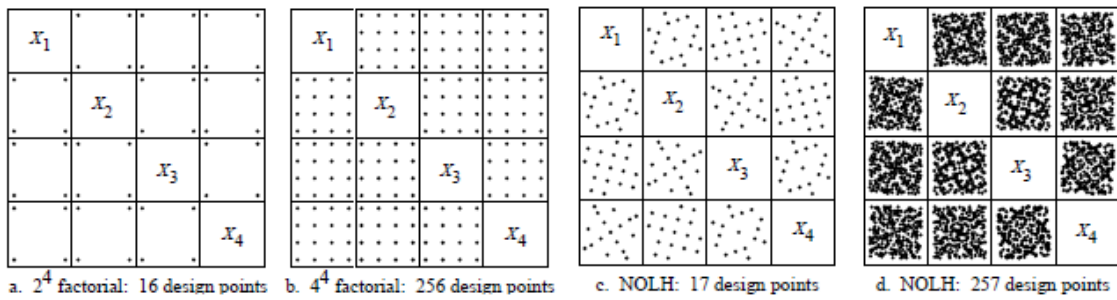
Figure 8. Space Filling Designs. Source: Sanchez & Wan (2012).

In this thesis, DOE is used to gain insight on the effects of MSM's inputs on its various output measurements, the response surfaces. This experiment used 24 factors which were varied at chosen levels to produce a 257 design point NOLH DOE design. A NOLH design was chosen due to the quantity of inputs that drive the MSM, and in real life the HRDP. A more detailed description of DOEs usage for evaluation and analysis is revealed in Chapter IV. In closing, using DOE as an evaluation tool allows a user to identify a model's inputs cause-effect relationship with the model's outputs, and therefore facilitates the ability to derive how the processes in a model are interacting at an abstract level.

III. MSM SIMULATION MODEL

The purpose of this chapter is to annotate the architecture and mechanisms that make up the MSM model. We first examine the MSM from a high-level approach, starting with the methodology used in constructing the MSM and giving an overview of how the program runs. We then move into examining the finer mechanisms that drive the MSM. This includes the various modeling controls that facilitate the execution of the program, the inputs that set parameters and establish data table look-ups, as well as dissecting MSM's simulation processes to show the individual components that drive the model. Finally, we examine the outputs the MSM produces.

A. DEVELOPMENT APPROACH

The MSM is a computer simulation model, programmed in the Java language that uses the capabilities associated with agent-based simulation to capture various manpower metrics during its simulation. For the MSM, Marine Agents serve as the individual agent instances that navigation through the simulation. A bottom up development methodology was used when constructing the MSM. With this approach, the developer identified the numerous individual manpower processes of the HRDP, built them as Java classes with their own state properties and unique behavioral methods, and then aggregated these processes to establish the manpower throughput of the HRDP.

B. PROGRAM EXECUTION OVERVIEW

The processes that the MSM uses are aggregated in a specific order to accomplish key phases of the MSM program as it runs. At a high-level view, this aggregation is organized into five phases. These phases are annotated as the user input, database pull, system initialization, simulation, and data output processing. The progression of these phases, with the specific processes internal to them, is shown in Figure 9 as a flowchart where the rectangles represent phases, and the circle nodes inside them represent specific event processes. Out

of these phases, the Simulation Phase is the main phase that drives the simulation. This phase is responsible for simulating the careers of all the Marine Agents, which ultimately gets captured as MSM's manpower output measurements.
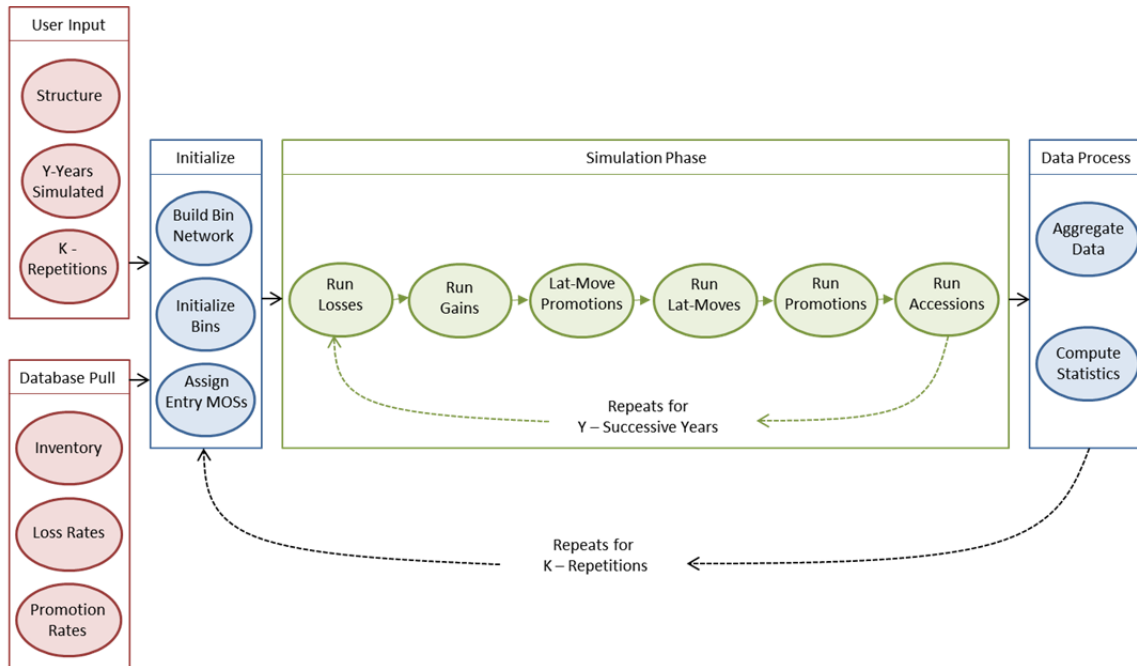
Figure 9. MSM Program Flowchart. Adapted from Garrick (2014).

The MSM is a time-step simulation where the metric for advancement is a one-year increment within the simulation phase. This means that all Marine Agents complete a singular process before being shuffled to the next process. As such, each Marine Agent is subject to losses, gains, promotions, lateral moves, and accessions once per fiscal year before the simulation increments by a fiscal year and repeats itself. This process progression can therefore be viewed as a waterfall structure; once one process is completed all Marine Agents move forward as a group to the next process. The inner components of these processes are documented as event graphs in Section E of this chapter.

C.   MODELING CONTROLS

Facilitating the execution of the MSM are the simulation controls that guide Marine Agents through their simulated careers. These controls include the network that Marine Agents use to advance in their careers, the rules and conditions that bound the Marine Agent to actual HRDP processes, and the usage of randomness to simulate non-deterministic decisions that occur within the HRDP.

1.   Structure

The foundational control mechanism of the MSM is the state graph network. This network represents the actual manpower structure of the Marine Corps where each state is associated to a direct MOS-Grade pair. This architecture was specifically chosen as it mimics the GAR. As previously discussed in Chapter I, the GAR is a manpower document that sets target quantities for every MOS-Grade pair in order to account for the Marine Corps range of manpower specialties and grade-experience while conforming to that fiscal year's end strength ceiling constraint. A snapshot of a GAR can be viewed in Appendix B. These MOS-Grade states are connected by a directed graph. This directed graph specifies which MOS-Grade state a Marine Agent can transition to as it simulates its career. Figure 10 illustrates a snapshot of this MOS-Grade state directed graph. Specifically, states are shown as circles and the specific MOS-Grade a particular state is representing is annotated in its center. Arrows link states to each other, with the arrows direction representing the transition direction a Marine Agent can make. When aggregated with all MOS and Grade combinations, these states and transitions make up the directed graph network for the MSM. With respect to constructing this network, the MSM uses a GAR file input to instantiate all the MOS-Grade states for a simulation, and a MOS data Excel spreadsheet input to establish the state to state transition possibilities. More information regarding these inputs is revealed in Section D of this chapter.
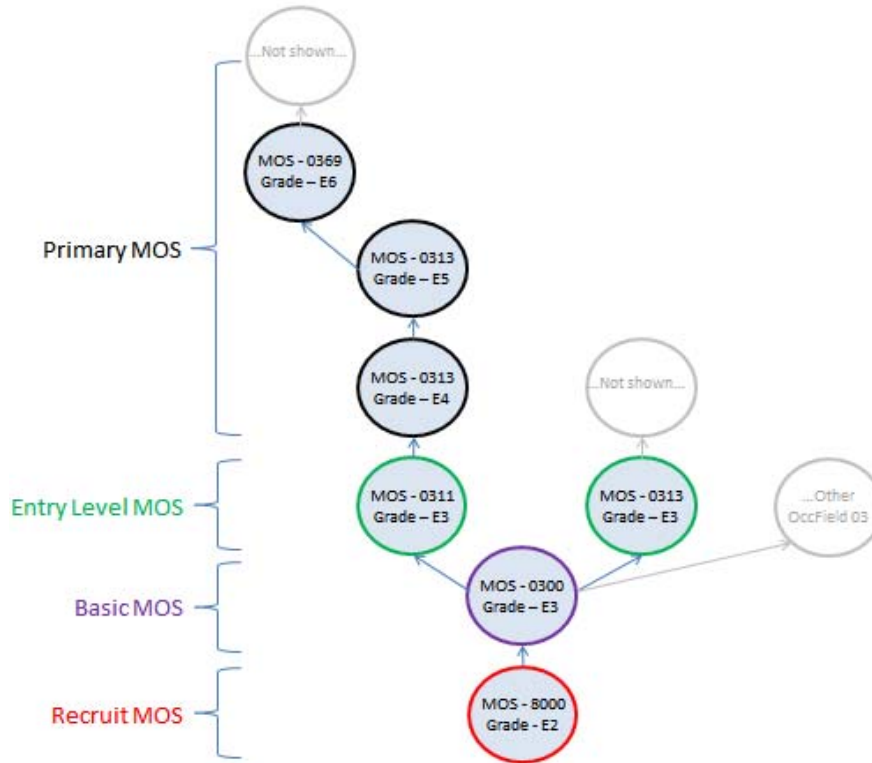
Figure 10.   MOS-Grade State Network Snapshot.
Adapted from Garrick (2014).

Figure 10 also shows the progression for MOSs from a recruit to a primary MOS. The four categories of MOS progression are: Recruit MOS, Basic MOS, Entry Level MOS, and Primary MOS. An important item to note is that the GAR input does not specify data for E1 and E2 grades, which means the MSM does not instantiate those Recruit MOS states. To circumvent this data interface the MSM translates the distribution of Basic MOSs into probabilities for the E3 grade sample space, and then randomly selects a MOS to assign a newly instantiated Marine Agent to. This meets the intent of the GAR as greater demand MOSs have a higher likelihood of being selected by the MSM's random number generator. However, this initialization for E1 and E2 grades only occurs once when a simulation run is invoked. The remainder of MSM's program execution uses the accessions process to properly simulate for these entry grades. More information about the MSM's processes is discussed in Section E of this chapter.

Besides for providing the progression network that Marine Agents navigate through, all MOS-Grade states retain specific functionality within the MSM. First, they act like a container bin. All MOS-Grade states keep a tally of Marine Agents that occupy that state. Conditional rules within the MSM's source code require space availability within a MOS-Grade state for a Marine Agent to transition into it. This ceiling is established within the MSM by the GAR input. Additionally, MOS-Grade states retain metadata for that state. This data eventually becomes the predominance of the output measurements produced by the MSM. Metadata that each MOS-Grade state retains includes:

- Predecessor states that are connected to it.

- Successive states that a particular state can direct to.

- Loss and Gain type categories.

- Quantity of losses and gains, per HRDP subcategories, captured in monthly increments.

- Retention metrics; to include quantity of Marine Agents eligible for retention and quantity of Marine Agents actually retained.

- Promotion metrics; to include quantity of Marine Agents eligible for promotion and quantity of Marine Agents actually promoted.

2. Deterministic Processing

Reinforcing the foundational control provided by the MOS-Grade state directed graph network are the deterministic processes that drive Marine Agents through the simulation. These processes are executed through rule-based decisions and are utilized when the outcome of a decision can be simplified into a binary option. Boolean conditions are leveraged within if-else statements, switch statements, for-loops or while-loops, and many other methods to navigate a particular process's algorithm. This control approach is deterministic because an identical Marine Agent, under the same inputs and same parameters, will select the exact same edge transitions to navigate down the same career path every time. A few examples of binary rules the MSM uses to select edge transitions are:

- Has the Marine Agent received the maximum allotment of promotion Passovers?

- Can the Marine Agent lateral move to a new MOS?

- Is there availability within a particular MOS-grade state for a Marine Agent to transition into?

3. Non-deterministic Processing

Non-deterministic processing can be categorized as the process where given the exact same input conditions when repeating a process, a different output verdict can be selected (Sanchez, 2007). This is also the process that gives the MSM its stochastic modeling functionality. Within the MSM, this is seen in situations where identical Marine Agents, under the exact same conditions and inputs, will select different edge transitions to navigate down for their simulated career. In event graph terminology, this is the process of selecting a transition edge that will identify the specific next event that will be executed.

Non-deterministic processing is used within the MSM to simulate decisions a Marine Agent would have to make; an example of such would be deciding to reenlist or transition out of active service at the expiration of their enlistment contract. Non-deterministic processing is also leveraged to select Marines at various boards within the HRDP; an example would be the final selection process of selecting Marines to be promoted from a sampling pool filled with qualified candidates. Non-deterministic processing is also used to incorporate non-idealistic random events that occur within the Marine Corps HRDP process; cases of deaths, deserters, or legal holds just to name a few.

The execution of non-deterministic processing is carried out by employing the Mersenne Twister random number generator in two different methods. We will classify these two different methods as a percentage line selector and a Bernoulli Trial. The percentage line selector incorporates most the characteristics of a Markov Chain model, however for only one transition instance per invocation.

In a percentage line selector, the potential outcomes are categorized and bounded on a percentage line that ranges from 0 to 100 percent. The outcomes are weighted such that events that are more likely to occur will receive a larger range selection on the percentage line. This weighted value is determined by historical data that is input into the MSM and translated into a percentage rate value. All possible transition events are then positioned on this percentage line such that they are all mutually exclusive, they are fully married next to one another, and they are normalized to fit the entirety of the percentage line. Finally, the random number generator generates a random percentage that will map to a singular outcome. This outcome is the decision point for that event and maps to the edge transition that particular Marine Agent will navigate down. Figure 11 illustrates this method.
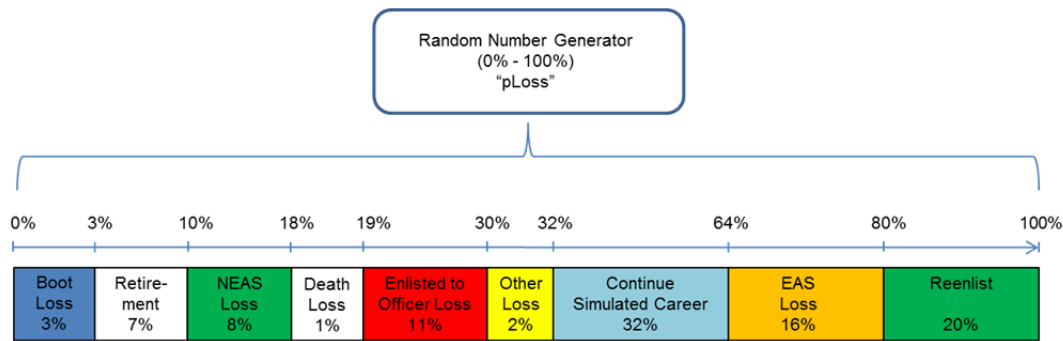
Loss subcategories are not drawn to scale, and their respective values were arbitrary created for this illustration. Intent of this illustration is to show how the loss subcategories marry up on a number line, that they sum to 100%, and that the Mersenne generates a random "pLoss" percentage used to execute one of the potential subcategories.

Figure 11.   Loss Subcategories Viewed on Number Line.
Adapted from Garrick (2014).

The second non-deterministic processing method used is a Bernoulli trial. This method is used specifically within the MSM to simulate the occurrence of those non-idealistic events, as well as other unique success and failure cases. In this method, a look-up table is referenced to set a threshold that will serve to delineate a trail's success or failure. This success or failure is then mapped to the

event decision. The Merseene Twister is again used to generate a random number that is translated to a percentage, and then referenced to the Bernoulli trial to select a course of action for that singular trail.

D.   MSM'S INPUTS

The MSM requires numerous inputs in order to run its program. The insertion of these inputs occurs at two file/folder locations, where the data inserted at these locations are either directly translated to parameters within the simulation or are used to reference Marine Corps online manpower archive databases. Figure 12 illustrates these inputs in a tree structure. The nodes outlined in red illustrate which inputs are directly translated into MSM parameters. The nodes outlined in blue illustrate which inputs are used to reference online databases. The bullets within the tree show the itemized inputs.
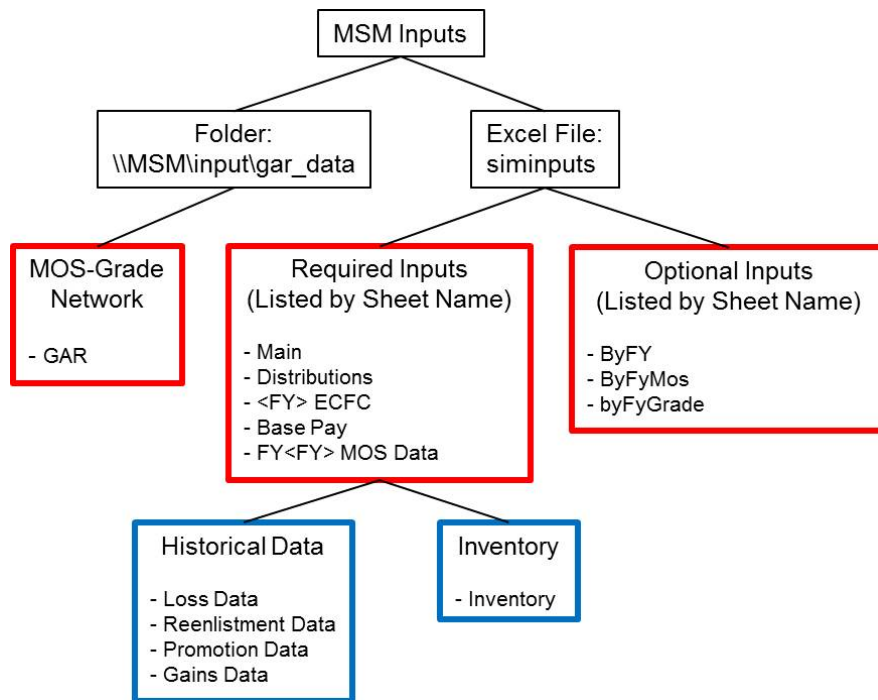
Figure 12.   MSM Inputs Shown in Tree Structure.
Adapted from Garrick (2014).

1.   Direct Inputs

The first location that direct inputs are inserted into is the "\\MSM\input\gar_data" folder. Within this folder, the user will manually insert GAR files into the folder where each file yields information for a single fiscal year. These file names must be changed to follow a standard naming convention of "nnenl<FY>.gbl" and "nnenl<FY>.tre" for the GAR build reports and allocation of training reports, respectively, where "<FY>" is replaced with the two-digit fiscal year the document represents. There is no limit to the number of GAR files inserted into this folder, only that GAR file fiscal years need to match the range of years the MSM program will forecast through. However, if the user chooses to forecast into the future where no GAR file exists, the MSM will reuse its previous FY GAR input for the next simulated year. It is critical that these preparatory details are followed as the MSM's source code is hard-coded to look exactly in that folder for exactly those file names. If the file names are in the wrong location or labeled incorrectly, the MSM program will not be able to pull the required data and construct its MOS-Grade state network, which will therefore crash the program.

The other direct inputs are all inserted into the "siminputs" Excel file. This document is broken down into eight sheets, where each sheet is associated with a particular HRDP process its inputs will influence. The following sheets require values to be input by the user:

- Main: includes simulation forecast y-years for k-repetitions

- Career force controls

- Pay data

- Monthly boot camp shipment distributions

- MOS data. This sheet is responsible for providing the series of rules that affect Marine Agents and how they transition to the various MOS-Grade states

The Excel file "siminputs" also contains sheets where the user is afforded the option to insert non-mandatory inputs. These inputs allow the user to quickly

alter some of the simulation parameters to specifically target certain case scenarios. Section E of this chapter will go into much further detail, but at an overview level, some of the MSM's Simulation Phase processes use algorithms that invoke the functionally to scale the results for a particular process. What this means is if the optional user data input is higher or lower than what the MSM is using as its baseline value, the MSM will increase or decrease its results, respectively. This scaling is also done proportionally to the percentage difference between the user input and the MSM's baseline value. A perfect example of this functionality is if a user wanted to re-run a simulation but for a different targeted fiscal year end strength. The user could quickly insert that value into the optional spreadsheet and receive an ad hoc assessment without having to go through the lengthy process of completely rebuilding the GAR files. The sheets these optional inputs can be found in are:

- Fiscal Year Targets

- MOS Targets

- MOS and Grade Targets

Additional details regarding these inputs can be found in Appendix A.

2. Reference Inputs

The other type of input that facilitates the MSM's functions is the reference input. These indirect inputs are the historical data the MSM pulls from an online Oracle database. Two types of data base pulls occur here: acquiring historical data of manpower pyramid transition rates, and inventory. These database pulls provide historical data that the MSM uses to compute its various probabilities of a Marine Agent executing a specific edge transition. The MSM facilitates the ability to pull from two different databases: Total Force Data Warehouse (TFDW) and Operational Data Store Enterprise (ODSE). TFDW and ODSE are very similar in the data they contain. The TFDW stores historical information at the one-month increment. Specific month's data can be obtained by providing the specific sequence number mapped to that month. Conversely, the ODSE maintains real-

time manpower metrics vice historical data, therefore providing the user an exact inventory of today's force. The data pulled from these databases includes:

- Loss data

- Reenlistment data

- Promotion data

- Gains data

- Recruit loss data

The other type of database pull is the inventory pull. This pull obtains a real sight picture of the manpower layout within the Marine Corps at a specific point in time. This means each real historical Marine becomes represented as a Marine Agent in order to initiate the MSM. The attributes for each Marine pulled are:

- Primary military occupational specialty (PMOS)

- Gender

- Years of service (YOS)

- Time in grade (TIG)

- Expiration of current contract (ECC) Year

- ECC Month

- Grade Selected For (if pending an approved promotion)

E.   SIMULATION PHASE

As Figure 9 showed, there are five phases that make up the MSM program. The first three phases are responsible for establishing the MSM's environment. This includes reading in user inputs, pulling reference data from online data repositories and storing that information within MSM local data tables, and then initializing the MSM MOS-Grade state graph network in terms of constructing the network and then populating it with the initial distribution of Marine Agents. Once these three phases conclude, the program is ready to enter the simulation phase.

The simulation phase is the main phase of the MSM as it is responsible for simulating the specific HRDP processes. This phase simulates for a user specified number of years. Specifically, after the last process within the phase has concluded, the MSM either will increment to the next fiscal year and repeat the simulation phase or, if all forecast years have been simulated, the MSM will increment to the data aggregation phase. When simulating a single-year iteration, the following manpower processes are executed in the following sequence:

1. Losses/Retentions

2. Gains

3. Lateral move with simultaneous promotions

4. Lateral moves

5. Promotions

6. Accessions

After the sixth and final process, the program stores its calculated metrics and determines its next course of action. If there are still additional years left to forecast, the program iterates and continues simulating for the following year. If the MSM has concluded its final year forecast, the simulation resets all its values and will repeat for a user specified number of times. This repetition allows for the stochastic properties of the simulation to take effect.

1. Losses Process

This process of the simulation model handles the attrition aspect of the HRDP. Each Marine Agent within the simulation is pulled and run through a trial to determine whether that Marine Agent continues their simulated career or if they have been randomly selected to exit the Marine Corps. In the losses process event graph, there are two major decisive event-nodes that occur. The first examines the Marine Agents years of service (YOS) in a simple if-else statement. If the Marine Agent's YOS exceeds the maximum time in service (maxTIS) constraint, as annotated by the user in their ECFC inputs, then the

Marine Agent has reached service limitations and is force to exit the Marine Corps. If cleared, the Marine Agent continues to the second decision node where they undergo a percentage line selector, non-deterministic trial, to determine if they will be categorized as one of the possible losses, or if they will continue their simulated careers. This trial references MSM's data tables, which were constructed by the reference input-type, to look up historical loss percentages for the various loss categories. Data for each loss category is categorized by three parameters. The three parameters used are:

- Grade

- Inventory type: if the Marine Agent's ECC is the current simulation year, they are annotated as "eas-0." If the ECC is the following simulation year, they are annotated as "eas-1." And if their ECC is beyond that, they are annotated as "neas."

- Retirement condition: if the Marine Agent is eligible for retirement, they are annotated as "re." Otherwise, they are annotated as "nre."

The percentage is calculated by dividing a loss category by the total inventory. Whichever edge condition meets the generated percentage becomes the edge transition that is executed. Reference Figure 11 to see an illustration of the percentage line selector non-deterministic method. If the Marine Agent transitions to a lost event, they are removed from the MOS-Grade state graph network, which creates inventory vacancies for that specific MOS-Grade. This process is shown in Figure 12 as an event graph.
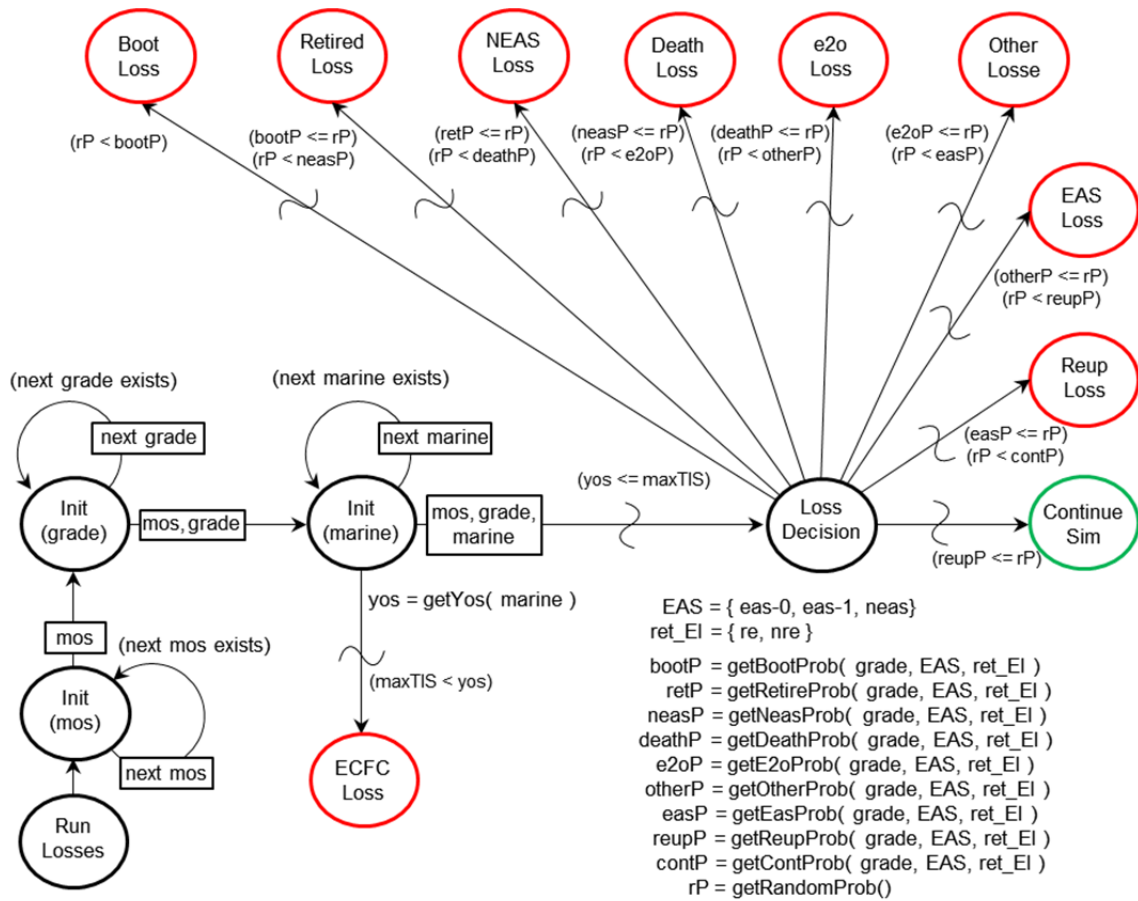
Figure 13.   Losses Event Graph. Adapted from Garrick (2014).

Before this process ends, the model checks to see if the optional input retention quantity was entered by the user. If so, the program will check to see if its original calculation has exceeded this user input threshold. If a zone is under its user defined retention zone threshold, no further action will occur. If a zone is over its threshold, the program will randomly select a Marine Agent from the retention container, re-classify them as EAS, and remove them from the state-graph. This itemized removal continues until the specified retention zone is under its maximum threshold.

2.   Gains Process

The Gains Process simulates the real world scenarios when prior service Marines return back into the Marine Corps inventory and are counted toward the

Marine Corps' overall end strength. As described in Chapter I, this can occur for a variety of reasons; such as returning from recruiting duty or returning from a medical hold. This process is executed by a Bernoulli, non-deterministic, trial. Specifically, every time a Marine Agent is tried in the losses process, the gains process is invoked and ran in parallel. One Bernoulli trial is run for each possible gain category (gainCat) per each process invoked. Look up tables, which were constructed by the MSM's reference inputs, yield the trial success probabilities for each gainCat. Three parameters are used to determine the specific percentage to use for each trial:

- gainCat

- Grade

- Base inventory for that grade

The percentage is calculated by dividing the quantity of a particular gainCat for the identified grade by the base inventory for that grade. Figure 14 displays the event graph for the Gains Process.
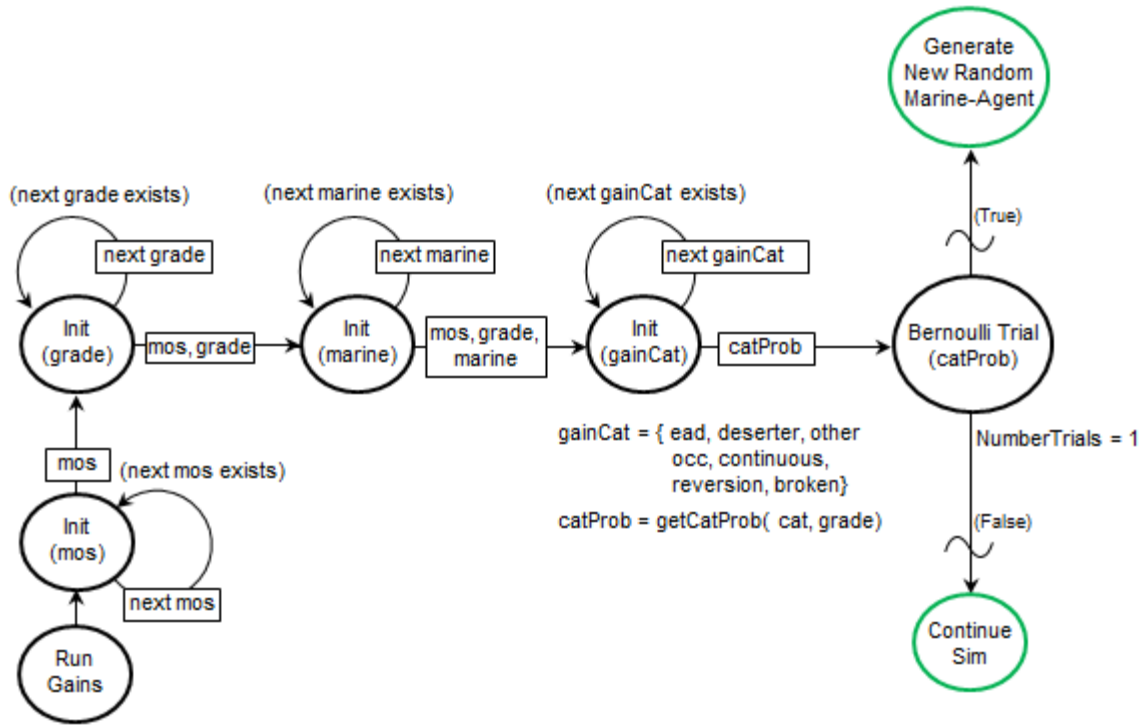
Figure 14. Gains Event Graph. Adapted from Garrick (2014).

If the Bernoulli trial was successful, the MSM will instantiate a new Marine Agent and insert them into the MOS-grade state network. To accomplish this, the MSM randomly generates all required Marine Agent attributes which include:

- YOS

- Time in grade (TIG)

- ECC

- PMOS

- Grade

- Month gained

3. Lateral Move Promotions Process

The Lateral Move Promotions Process is the third process invoked during the Simulation Phase. It combines the lateral move process, where a Marine Agent obtains a new MOS within the same grade, with the promotions process,

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where a Marine Agent obtains a higher grade but within the same MOS. This can be summarized as a simultaneous horizontal and vertical move within the MOS-Grade state graph network. This process is unique in that it only targets the small population of Marine Agents with MOSs that allow for career progression to new MOSs, lateral moves. This rule constraint is constructed from the direct input "FY<FY> MOS data," which is an Excel sheet that resides within the "siminputs" Excel document.

The lateral move promotions process was strategically placed to precede the regular lateral move and regular promotion processes due to the inventory quantity of Marine Agents they each contain. This means Marine Agents that have the potential for a new MOS are given the opportunity to fill vacant billet spots in other MOS-Grade states before Marine Agents with standard career progressions. If these processes were reversed there would be a much greater probability that all potential MOS-Grade states would be filled by standard career progression Marine Agents, leaving lateral move promotable Marine Agent candidates stagnant.

The Lateral Move Promotions Process is also the first process where the procedural priority for processing Marine Agents is critical. This stems from the constraint that a state must possess billet vacancies in it to allow a Marine Agent to transition to it. To accommodate this, the MSM examines Marine Agents in reverse grade order; starting with the grade E9 and then working downwards. This allows Marine Agents to move into higher billet vacancies immediately, which therefore creates a billet vacancy in the MOS-Grade state they just left. This effect trickles downward to the lowest grade of Marine Agents.

The algorithm for the lateral move promotions process contains five steps. Figure 15 shows this process in event graph form. In procedural order, the algorithm's steps are annotated as:

1. Select a MOS-Grade state for Marine Agents to lateral move and promote into.

2.   Build a list of Marine Agents that are allowed to be laterally moved and promoted into the identified MOS-Grade state.

3.   Count the number billet vacancies within the targeted MOS-Grade state. This is accomplished by obtaining the delta between current occupancy and maximum allowed occupancy as dictated by the GAR input.

4.   Check if the optional input "End Strength" was entered by the user. If it was, the MSM will take the percentage difference between the GAR's total strength and the user's optional input End Strength, and apply that percentage to the MOS-Grade states to increase or decrease the total amount of billet vacancies respectively. If the user did not enact this option, the program will use the number of billet vacancies found in step 3.

5.   While billet vacancies and Marine Agents exist, randomly select a Marine Agent to execute the lateral move and promotion transition.
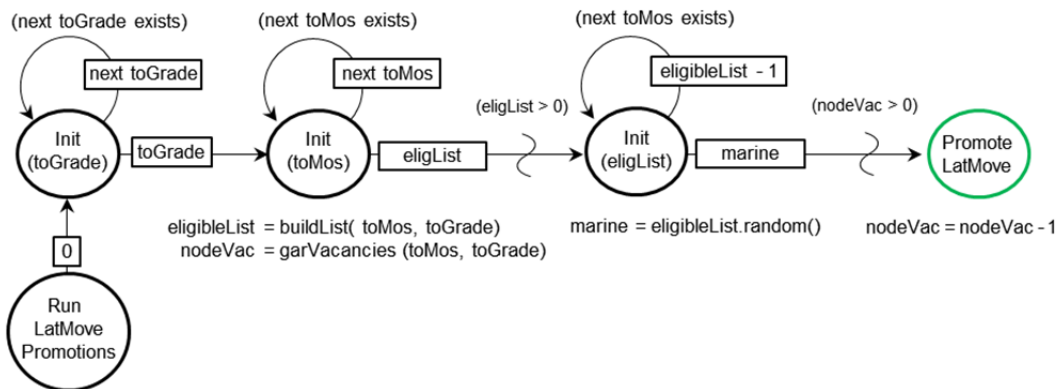
Figure 15.   Lateral Move Promotion Event Graph.
Adapted from Garrick (2014).

4.   Lateral Move Process

The lateral move process follows the exact same methodology as the lateral move promotions process except for two critical areas. First, the process will only move Marine Agents horizontally to a new MOS; so the Marine Agent will maintain their same grade. Secondly, this process incorporates P2T2 possibilities into its algorithm. Specifically, being selected by the board does not guarantee the Marine Agent will transition to their updated MOS-Grade state.

Instead, the algorithm simulates whether or not the Marine Agent will be placed back in the state-graph or if they will be placed into the P2T2 container for that fiscal year. This decision is made by referencing the length of the school, time to train MOS metric, the Marine Agent would have to attend to learn their new trade. If the school is longer than 365 days, one-year, the algorithm directly places the Marine Agent into the P2T2 container since they will be without a doubt still in school when that fiscal year ends. If the school length is shorter, the algorithm calculates the probability of being at that school at any particular point in the fiscal year where the probably is the duration of the school divided by 365 days. Once calculated, this percentage is passed to a Bernoulli, non-deterministic, trial where one trial is run. If the Bernoulli trial was successful, then the model will place the Marine Agent into the P2T2 container. Otherwise, they will return to the state-graph at their updated MOS-Grade state. Figure 16 shows this process as an event graph.
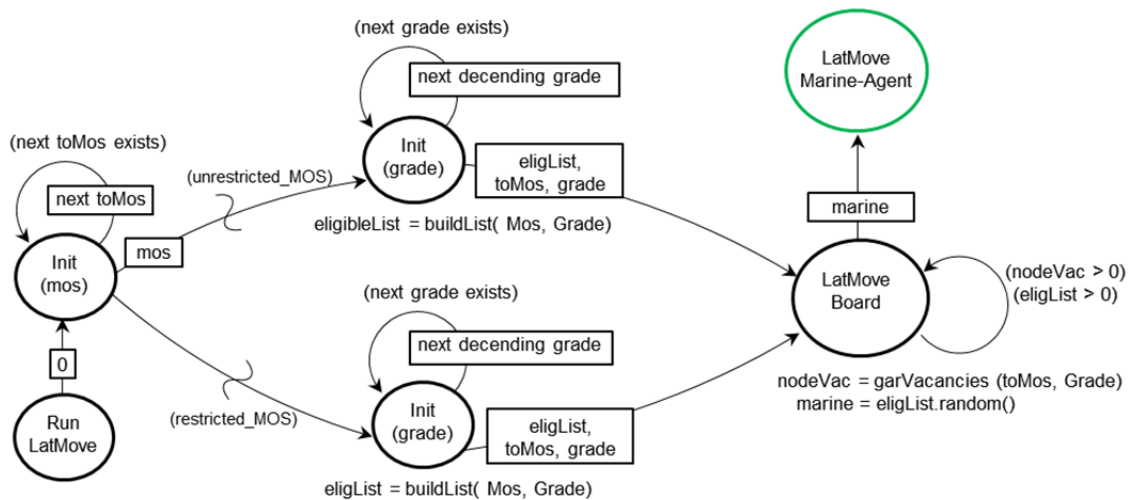

Figure 16. LatMove Event Graph. Adapted from Garrick (2014).

5.   Promotions Process

This process compliments the previously stated lateral move promotions process in that it is the mutually exclusive counterpart to the lateral mover indicator. Specifically, this process focuses promoting Marine Agents who do not

possess MOSs that allow for lateral moves. Non-lateral move MOSs comprise of approximately 95% of the total MOS inventory (Spafford, 2016). Therefore, it is to no surprise that the algorithm steps and event graph, shown in Figure 17, are identical.
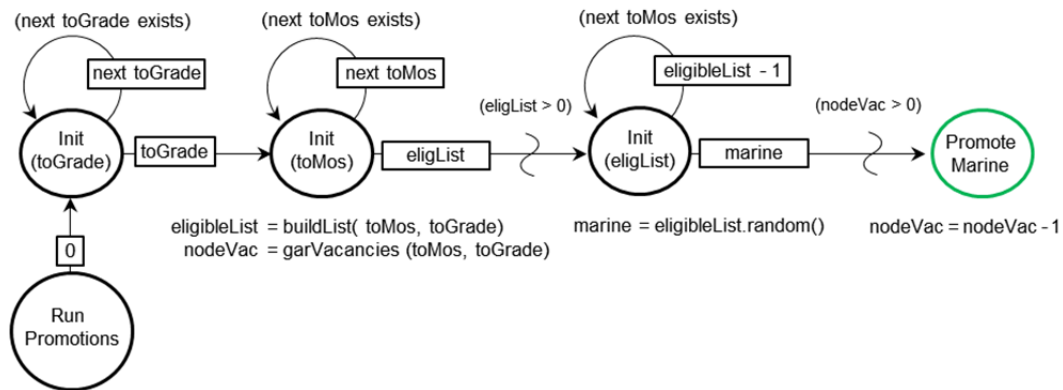
Figure 17.   Promotions Event Graph. Adapted from Garrick (2014).

6.   Accessions Process

The accessions process is the final process of the simulation phase and is predominately summarized as the overall backfill of all MOS-Grade state vacancies that have trickled their way down to the junior grade levels. The algorithm is conducted by executing the following steps.

1.   Set baseline accession targets per MOS: This is accomplished by aggregating the current inventory in the MOS-Grade state graph network for grades E1 through E3, categorizing by MOS. It then subtracts that MOS's entry level aggregate from the GAR's allowed quantity, which is the GAR column labeled "E3." The initial aggregation of the MSM's current entry level inventory is required due to the data interface constraint with the GAR; that is the GAR does not identify MOS quantities for grades E1 and E2.

2.   Distribute MOS targets to entry level grades: By default, the MSM takes step 1's deliverable and distributes them to the paygrades E1, E2, E3, within that MOS, by the constant ratio 75.84%, 24.15%, and 0.01%, respectively. However, if the user set the optional MOS

accession targets in the siminputs Excel document, the paygrade distribution will be applied to this quantity vice step 1's deliverable.

3.   Set MOS-Grade male and female targets: The MSM takes step 2's deliverable and then divides that quantity into male targets and female targets. By default, this distribution is calculated by the MSM's reference input from the historical Marine Corps Oracle online databases. However, if the user sets the optional female accession targets in the siminputs Excel document, the male/female distribution will then be proportionately adjusted to match the user's target.

4.   Instantiate a Marine Agent: For every male/female MOS-Grade target, the MSM will instantiate a new Marine Agent. While the sex, MOS, and grade are already determined, the MSM will use its percentage line non-deterministic selector to randomly determine the contract length of the Marine Agent and the Month in which that Marine Agent entered boot camp. Contract length probabilities are set by the required user input 'FY<FY> MOS Data' sheet in the Excel file "siminputs."

5.   Test for boot camp loss, and insert into MOS-Grade state graph network: Each instantiated Marine Agent will be passed through a boot camp losses trail. This trial is very similar to the Losses process event graph. If a loss event is not selected, then Marine Agent is then inserted into their respective MOS-Grade state.

F.   MODEL OUTPUTS

At the completion of the Simulation Phase, the program records the data associated with that particular repetition run. The program will then iterate and run the entire simulation over again, using the same inputs, to obtain new output metrics. This repetition allows for stochastic properties to take effect. Once all repetitions have run, the program computes a statistical analysis of the different runs. This is called the data aggregation process. Each metric within the process is analyzed by its:

- Means

- Standard Deviation

- Maximum

- Minimum

These output measures are aggregated at three different tiers, where each tier yields the same data but at different levels of fidelity. Tier I data is the most abstract data output, where the data obtained from all the MOS-Grades are aggregated into a fiscal year sum. Tier II still aggregates its data into fiscal year sums, however it incorporates three possible classifiers the data can be sorted into: MOS, Grade, or MOS and Grade. Tier III expands off of Tier II in that it keeps the same classifiers, but the data drills into the monthly level. Figure 18 depicts this layered metric tier, and its respective scope of detailed information the Model's user is wishing to obtain. For Chapter III's Design of Experimentation, Tier I output data was utilized. For Chapter IV's Validation, a combination of Tier I and Tier II, with categorization by grade, output data was utilized. More information regarding the output measures, and their respective definitions and metric scope, is listed in Appendix D.
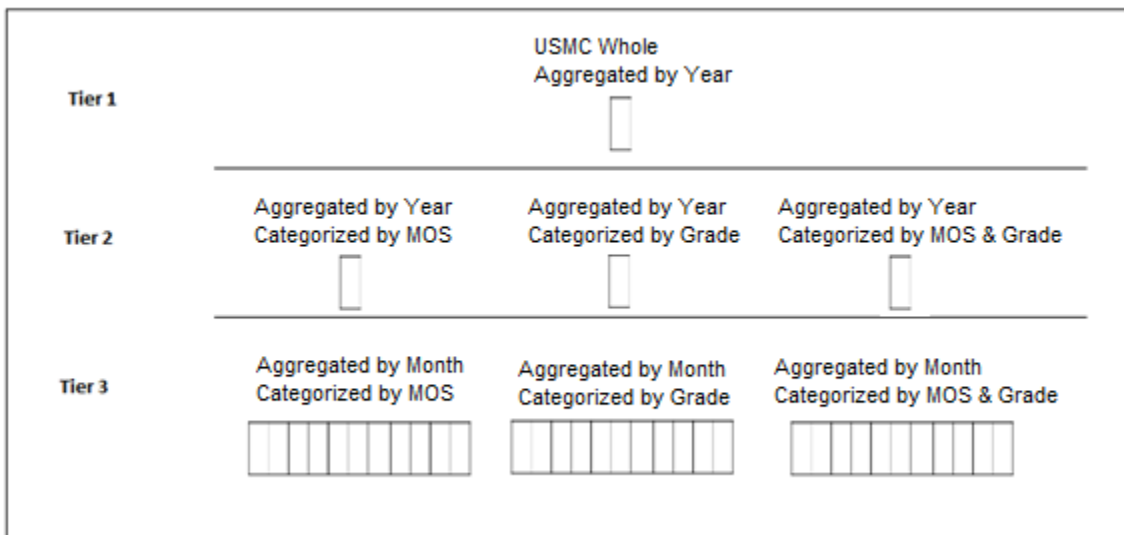

Figure 18.   Depiction of MSM's Output Metrics, Aggregated at Different Levels. Adapted from Garrick (2014).

IV. DESIGN OF EXPERIMENTS EVALUATION

This chapter describes the design, procedure, and experimental results used for conducting the design of experiments (DOE) evaluation. This evaluation provided two key metrics; it verified the input-to-output response correlation, and it identified the input significance priority. Correlation is the process of looking at two variables and determining if one influences the other. This influence can be either strong or weak and incorporates the direction, positive or negative, toward which the variables will react (Law & Kelton, 2000). This strength and direction relationship is often referred to as the correlation gradient (Law & Kelton, 2000). Within this DOE evaluation, gradient was the primary metric for measurement used as it allowed for cause-effect HRDP relationships to be easily identified and analyzed.

The second evaluation metric was the input significance priority. Input significance priority is the nomenclature used to identify which terms were responsible for having the most impact on the produced metamodel. This is determined by computing the ratio between the parameter coefficient within a metamodel's response surface equation and its standard error ("Estimates," n.d., Sorted Estimates section). Terms with a higher level of significance identify which inputs are more sensitive in forecasting future data predictions.

To compute statistics from the DOE experiment, we used the statistical software suite JMP Pro 12. An overview of the functionality utilized is described in Section B of this Chapter.

A. CONSTRAINTS AND DESIGN

This section describes the constraints that were presented in subjecting the MSM to a DOE. It highlights the decisions made to comply with these constraints, to include what the final DOE design entailed.

1.   Factor Selection

DOE is naturally limited by the number of factors it can take in and create a design from. This limitation stems from the computational costs required in conducting an experiment with a large set of factors while simultaneously maintaining the experiment's orthogonality. The largest NOLH that exists today allows for up to 29 factors, which produces a 257-design point design (Cioppa & Lucas, 2007). A Nearly Orthogonal Balanced design is a different type of DOE design that does allow for more factors to be used (Vieira Jr. et al, 2012). However, this design incorporates a mix of discrete and continuous factors that did not interface well with the MSM and therefore was discarded.

Condensing MSM's numerous inputs to map to 29 DOE factors proved challenging. This problem stemmed from MSM's multi-dimensional look up tables that are constructed from its reference input Oracle database pulls. Take for example the loss rate inputs for just the loss subcomponent EAS. This subcomponent takes the parameters of MOS, Grade, and Retirement Eligibility to look up the specific EAS rate within those dimensions. Just those EAS loss rates yield 4320 inputs; 240 MOS x 9 Grades x 2 Retirement Options = 4320 inputs. Extrapolating this multi-dimensionality across the other HRDP process categories unquestionably exceeds a NOLH factor threshold. To circumvent this constraint, we implemented the use of abstraction within our DOE.

With the abstraction methodology, we targeted the specific subcomponent of a HRDP process as a single DOE factor vice assigning a factor to every input in its multi-dimensional table. With this approach, the DOE factor acted as a coefficient that adjusted the subcomponent it was representing. Because this subcomponent was uniformly adjusted every time a value was returned from the look up tables, the orthogonality of the experiment was maintained.

Table 1 illustrates the application of this abstraction methodology. Specifically, the table provides a snapshot of the "Continue Rate" category, which is a subcomponent of the losses HRDP process. As the table shows, its multi-

dimensionality yields six inputs for just a single grade return. The original inputs are annotated in the column "Continue Rate" and serve as the baseline. The column "NOLH Factor" reflects what that DOE factor is set at for that particular design point. Acting as a coefficient, the "NOLH Factor" is multiplied with the baseline to produce the adjusted input; labeled "Function Rate." This adjusted rate is what is returned to the function, allowing that HRDP process's algorithm to continue its execution in alignment with the DOE design point.

Table 1.   Snapshot of Factor Adjust Rates.
Adapted from Garrick (2014).

Grade	Retirement Condition	Inventory Condition	Continue Rate	NOLH Factor	Function Rate
E5	nre	neas	96%	96%	92%
	nre	eas-0	21%	96%	20%
	nre	eas-1	87%	96%	84%
	re	neas	100%	96%	96%
	re	eas-0	67%	96%	64%
	re	eas-1	100%	96%	96%

Loss rates are pulled from the Marine Corps online Oracle database and stored locally within the MSM program for the simulation. Local data tables contain three dimensions: grade, retirement condition, and inventory condition. Retirement condition uses the codes "re" and "nre" to identify the parameters of being retirement eligible and not retirement eligible, respectively. Inventory conditions use the codes "eas-0," "eas-1," and "neas" to identify a Marine EASing within the current fiscal year, EASing during the next fiscal year, and EASing beyond two years out, respectively.

After condensing MSM's inputs, a total of 24 factors were chosen to adjust the various inputs of the MSM. These factors are annotated in Table 2. The factors labeled "Loss_" or "Gain_" were factors that received the abstraction method. All other factors were direct replacements of MSM inputs. The columns "Low Value" and "High Value" indicate the lower and upper bounds design points could range within. The column "Decimals" indicates the number of decimal placeholders a design point's precision was set to.

Table 2.   DOE Factors and Their Ranges. Adapted from Garrick (2014).

Factor Name	Factor Description	Low Value	High Value	Decimals
TISmin	Minimum Time-In-Service (TISmin) required for a Marine Agent to be promoted to the superior targeted grade.	-2	3	0
TISmax	Maximum Time-In-Service (TISmax) allowed for a Marine Agent to remain within its current grade.	-4	4	0
TIGMin	Minimum Time-In-Grade (TIGmin) required for a Marine Agent to be promoted to the superior targeted grade.	-1	3	0
PromTgt	Promotion target (PromTgt) is the desired cumulative years of service to achieve a targeted grade.	-2	4	1
VIZmin	Variable In-Zone (VIZ) minimum is when mean promotion time for targeted grade is within limits, this standard selection opportunity is used.	-0.1	0.05	3
VizStd	Variable In-Zone (VIZ) standard is when mean promotion time for targeted grade is too slow, using VIZ minimum opportunity allows Marine Agents to compete earlier in their career, speeding up average promotion timing.	-0.05	0.05	3
VIZmax	Variable In-Zone (VIZ) maximum is when mean promotion time for targeted grade is too fast, using VIZ maximum opportunity reduces the number in zone, delaying opportunity to compete for junior Marines thereby slowing the average time in service for promoted Marines.	-0.05	0.1	3
PassO	Passover (PassO) specifies the maximum number of passovers a Marine Agent may have to remain within its current grade.	-2	2	0
ReThsh	Reenlistment threshold (ReThsh), if passover limit is reached, Marine agents may not reenlist beyond this threshold.	-2	2	0
Loss_Boot	The loss rate at which Marine Agents exit the Marine Corps during bootcamp.	0.6	1.1	3
Loss_Retired	The loss rate at which Marine Agents exit the Marine Corps due to retiring.	0.6	1.1	3
Loss_NEAS	The loss rate at which Marine Agents exit the Marine Corps with a Non-EAS separation code.	0.6	1.1	3
Loss_Death	The loss rate at which Marine Agents exit the Marine Corps due to death.	0.6	1.1	3
Loss_e2o	The rate at which Enlisted Marine Agents receive an enlisted to officer (e2o) commission, and therefore leave the enlisted manpower structure.	0.6	1.1	3
Loss_Other	The loss rate at which Marine Agents exit the Marine Corps due to other means not documented with a specific separation code.	0.6	1.1	3
Loss_EAS	The loss rate at which Marine Agents exit the Marine Corps due to the end of their enlisted contract called End of Active Service (EAS).	0.6	1.1	3
Loss_Reup	The rate at which Marine Agents reenlist.	0.6	1.1	3

Factor Name	Factor Description	Low Value	High Value	Decimals
Gain_EAD	The rate at which Marine Agents return from their extended active duty (EAD) recruiting tour.	0.6	1.1	3
Gain_Desert	Marine Agents that return after having become a deserter.	0.6	1.1	3
Gain_Other	Marine Agents that return to service for other means not captured.	0.6	1.1	3
Gain_OCC	The rate at which Marine Agents return to service with a OCC gain code.	0.6	1.1	3
Gain_Cont	The rate at which Marine Agents return to service with a Continuous gain code.	0.6	1.1	3
Gain_Rever	The rate at which Marine Agents return to service with a Reversion gain code.	0.6	1.1	3
Gain_Broken	The rate at which Marine Agents return from medical holds.	0.6	1.1	3

After solidifying the DOE factors, the actual DOE design was constructed. We used the Naval Postgraduate School SEED center's open source document, titled "NOLHdesigns_v6.xls, to construct our NOLH design of 24 factors and 257 design points (Sanchez, 2011). This open source document uses MACROs and hidden formulas within its template to automatically compute design point values for the design. The full design can be found in Appendix E.

To examine the design's orthogonality, we constructed a correlations plot by using JMP's multivariate methods functionality. The correlations plot illustrates how each NOLH factor relates to other factors. If the design was completely orthogonal, each comparison would have a value of zero. However, because the NOLH is a nearly orthogonal design, some relationships do exist. From the 24-factors selected as inputs, the top three correlations were:

- 0.0876 (TISmin with TIGmin)

- 0.0451 (TIGmin with GainOther)

- 0.0369 (Passovers with LossOther)

The full correlations plot of the NOLH design can be found in Appendix D.

2. Response Surface Selection

The MSM produces 71 different output metric categories. In theory, a response surface could be calculated for each MSM output metric, but that level of fidelity exceeded the scope of this thesis. Therefore, we used an aggregation methodology to analyze a HRDP process as a whole vice drilling into the individual subcomponents' response surfaces. This aggregated approach was applied to three HRDP process:

- Losses

- Gains

- Retention Zones A-SR

Other output metrics yielded data that was already holistic to a HRDP process and did not require aggregation. The four response surfaces that were measured with this approach were:

- Promotions

- LatMoves

- End Strength

- Patients, Prisoners, Transients, and Trainees (P2T2)

After selecting which output metrics we would compute response surfaces for, we then had to select what dimensionality of the output data sets we would analyze. As described in Chapter III, MSM's outputs allow the user to view forecasted manpower data either at an aggregated, holistic Marine Corps, level or it can drill down into the MOS-Grade level. Additionally, these data values can be viewed at monthly intervals or at an aggregated fiscal year level. To meet the intent of this thesis, we choose the data set that was holistic to the Marine Corps and at the fiscal year interval.

Additionally, because the MSM allows a user to specify how many forecast years it will simulate to and for how many repetitions, we had to isolate these parameters too. Ultimately, we decided the fourth forecast year's data

output would be analyzed because that is generally the first opportunity when enlistment contracts end. As for repetitions, to yield an appropriate distribution of MSM's stochastic capability, it was decided that each NOLH design point would be replicated 30 times. The average value from the replicated data sets was then used for evaluation.

3. Modeling Loss Constraints

As described in Chapter three, the losses process uses the percentage line non-deterministic method to select which loss event a Marine Agent will execute. Figure 19 illustrates this type of method. The method is predicated on the fact that the rates of all loss events are normalized onto the percentage line such that they always aggregate to a full 100% value. As a reminder, eight loss events and one continue simulation event make up the list of possible transition events a Marine Agent can execute:

- Bootcamp Loss Event

- Retirement Loss Event

- NEAS Loss Event

- Death Loss Event

- Enlisted to Officer Commission Loss Event

- Other Separations Code Loss Event

- EAS Loss Event

- Reenlistment Loss Event

- Continue Simulated Career Event

Normalization is ensured due to the structure of the supporting data tables and how the computations source code was written in the algorithm. Specially, the data look-up tables organize its data such that the losses table contains only the data used for computing the loss events. This ensures all loss events are mutually exclusive, and the entire loss-data sampling space will be used for processing one Marine Agent. This inherent setup becomes problematic for the

DOE experiment because the DOE Factors will adjust the rates of the loss events independently, and therefore, may yield DOE design points where the aggregation of loss events exceeds, or falls short of, the intended 100% value.
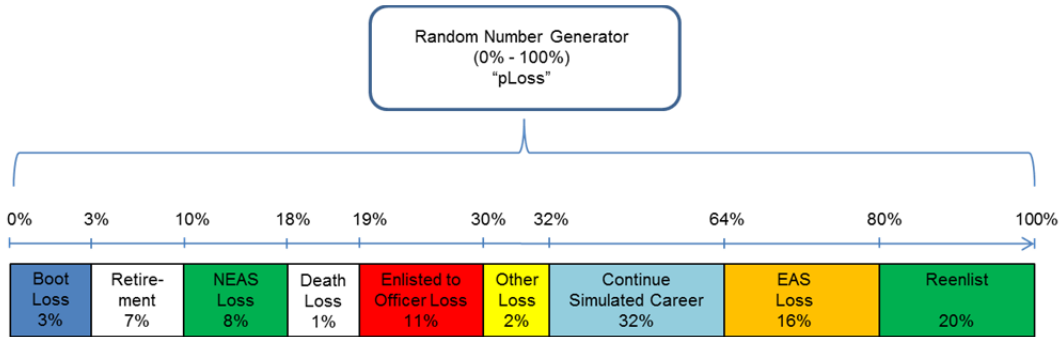
Loss subcategories are not drawn to scale, and their respective values were arbitrary created for this illustration. Intent of this illustration is to show how the loss subcategories marry up on a number line, that they sum to 100%, and that the Mersenne Twister generates a random "pLoss" percentage used to execute one of the potential subcategories.

Figure 19.   Percentage Line Non-deterministic Method.
Adapted from Garrick (2014).

After analyzing the constraint, three courses of actions presented themselves for how to proceed. The first option was to exclude the Losses Process from the NOLH design, and therefore not evaluate the process. This option was discarded because the loss function is one of the most important functions of the model. This is because the model tries to maximize its force structure by adding Marine Agents into the MOS-Grade state graph network but is limited by the constraint that there must be available vacancies in a MOS-Grade state for a Marine Agent to move into it. Therefore, if Marine Agents do not vacate a MOS-grade state the model becomes stagnant.

Option two was to include all possible transition events, allowing the NOLH design to adjust them independently, and then normalize them prior to running the execution statement block so they always summed to the full 100% value. This option was discarded as it greatly decreased the orthogonality between the factors.

The third option was to focus on the eight subcomponents that comprise the loss category, adjust each of them independently as the NOLH design dictates, and then use the ninth subcomponent "Continue" to absorb any remaining difference in the number line so that the statement block still sums to 100%. While the "Continue" subcomponent would no longer remain independent, the objective of the experiment would still be achieved because all the subcomponents that capture loss would still be varied independently, and therefore their inputs would be independently captured in loss's response surface. To ensure a "Continue" absorbing event had available space to exist on the percentage line, the DOE loss factors were bounded from 60% to 110% of their original baseline values. While this factor range focused on lower rate values, orthogonality of the experiment was retained with this option, and therefore still yielded accurate metamodels for this experiment. This was the option chosen to comply with the loss process's constraints.

4.   Scaling Constraints

As discussed in Chapter III, the MSM possesses the capability for a user to insert optional inputs. These optional inputs allow a user to build a specific case study to be simulated, or simply allows for ad hoc simulation adjustments. However, these optional inputs invoke scaling algorithms that sit on top of the Simulation Phase's processes. When these scaling algorithms are invoked, orthogonality of the DOE is not maintained since the values are being adjusted independently of the DOE's design points (Sanchez & Wan, 2012). Therefore, this DOE refrained from entering any values into the optional inputs.

B.   PROCEDURES

1.   Experiment

This experiment required two efforts to be executed. The first effort was to establish the baseline MSM inputs. This would be the baseline that the DOE factor's design points would adjust from. We set up the MSM to simulate four years, for 30 repetitions. For the reference inputs, we used the end of fiscal year

2013 data to initialize the MSM. The initial forecast year was therefore 2014. As previously annotated in Section A, no option inputs were inserted in order to refrain from invoking the scaling algorithms of the MSM. Table three illustrates the inputs inserted into the "Distributions" sheet of the input file "siminputs." Figure 20 illustrates the baseline Enlisted Career Force Controls (ECFC) used. Lastly, the "siminputs" Excel sheets "Base Pay" and "MOS Data" used the configuration data approved for fiscal year 2014, respectively.

Table 3.   New Recruit Shipping Distribution DOE Inputs

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
6.71%	7.93%	7.01%	7.01%	5.37%	7.87%	6.20%	4.16%	13.15%	12.08%	10.75%	11.76%

Grade	Service/Grad			Promotion Controls					Min Opportunity		Passover Controls			
	TIS Min	TIS Max	TIG Min	Promotion Target	Promotion Timing Tolerance (in years)	VIZ Min	VIZ Standard	VIZ Max	Minimum Looks	Max TIS To Achieve Minimum Promotion Opportunities	Passover Limit	Limit Type	Reenlistment Threshold	Max TIS Passover
E1	0	10	0	0	1									
E2	0	10	0	0	1									
E3	0	10	0	0	1									
E4	0	10	0	1.4	1									
E5	2	12	0	3.4	1									
E6	4	22	1	7.9	1	72%	77%	92%			2	ECC		22
E7	6	24	2	12.4	1	67%	72%	87%			2	ECC	21	24
E8	8	29	3	16.9	1	62%	67%	82%			2	ECC	23	29
E9	10	42	2	21.4	1	57%	62%	77%			2	ECC		42

Figure 20.   Enlisted Career Force Controls. Adapted from Garrick (2014).

The second experimental effort was the DOE experiment itself. To execute the DOE, we created an additional Java main class. The purpose of this test-main class was to control the DOE experiment while ingesting the next design point's inputs, running the MSM program for that design point, and then extracting the associated forecasted data. The general algorithm used by the test-main's source code was as follows:

1.   Extract NOLH design point inputs.

2.   Update MSM's input document "siminputs" with the respective design point values.

3.   Invoke the main MSM program to run the simulation with the updated inputs.

4.   Extract and record the output results.

5.   Repeat with the next design point's inputs.

2.   Analysis

To compute statistics from the DOE experiment, we used the statistical software suite JMP Pro 12. Specifically, the software provides a function called Fit-Model. With this function, the user selects the dependent and independent variables to run the JMP function. The dependent variable was the response surface of the particular metamodel being evaluated. The independent variables were the DOE input factors used in the experiment. JMP software uses the term "role variable" to identify the response surface and "model effects" to specify the relationship of how the independent input factors will be analyzed. Recalling from Chapter II, a NOLH design allows for main effects, two-way interactions, and quadratic effects to be examined. Within the JMP software, the DOE factors were used to construct the "model effects" by importing them as two groups, which produced a total of 324 DOE terms to be analyzed:

- Polynomial to 2nd Degree construction was used to view the main effects and quadratic effects terms for all the DOE design factors.

- Factorial to 2nd Degree construction was used to view all the two-way interaction terms of the model's effects.

Initially, JMP's stepwise regression was run to determine which input factors were selected as having a significant impact on the response surface of the metamodel. To accomplish this, JMP uses a Bayesian information criterion (BIC) for identifying significant terms. The mathematical formula used to compute BIC is shown in Equation (3), where k is the number of estimated parameters in the model and n is the number of observations in the data set ("Likelihood, AICc, and BIC," n.d.). This initial computation of significant terms reduced the number of terms to be analyzed by approximately 90%.

$$BIC = -2\log Likelihood + k\ln(n) \qquad (3)$$

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With the updated significant terms selected, JMP's Fit-Model was run a second time using a Standard Least Squares regression. This final regression produced seven statistical reports that enabled the analysis of each metamodel:

- Effect Summary: This report yields the "LogWorth values for the effects in the model" ("Effect Summary Report," n.d.). The mathematical formula to compute LogWorth is shown in Equation (4), where p is the term's p-value.

$$LogWorth = -\log_{10}(p)$$

(4)

- Actual by Predicted Plot: This plot visually shows the reader how well the produced metamodel fits the input data. In the case of our DOE experiment, the input data are design points of the NOLH. The actual versus predicted values are a comparison of what the model actual yielded during its stochastic computations compared to what the metamodel's response surface equation calculated.

- Summary of Fit. This statistical report provides numerous values which yield a statistical overview of the model. For this evaluation the adjusted R-Square value was used to normalize and compare the metamodels against one another because each model could have different numbers of identified significant terms. This number ranges from 0 to 1, where the closer the value is to 1 the better the model's fit is to the data. Its specific formula is shown in Equation (5); where MS is the means square from the model's source Error, the source of the sum of squares is the corrected total (C. Total), and DF is the degrees of freedom from the model's corrected total ("Regression Reports," n.d., Summary of Fit section).

$$Rsquare\_Adj = 1 - \frac{MS}{SumOfSquares / DF}$$

(5)

- Analysis of Variance. This report yields model calculated values, such as the mean square for the metamodels error used in Equation (5).

- Parameter Estimates. This report shows the estimates for all terms post *BIC* selection. These estimates represent the coefficients used in the response surface equation. This report also includes the Intercept estimate, which is referring to the intercept coefficient for the response surface equation.

- Sorted Parameter Estimates. This report shows the parameter estimates for each term, where each term is sorted in a decreasing

order of significance. Significance is determined by the absolute value of the calculated "t Ratio," which is the ratio of the estimate when compared to its standard error ("Estimates," n.d., Sorted Estimates section).

- Prediction Profiler. This report yields a visual that allows the user to gauge the sensitivity of the metamodel's terms, that is the response surface's gradient. As a quick reference, profiles that have a more horizontal orientation have little impact on the metamodel's output measurements as the term changes. Conversely, profiles that have a more vertical orientation are considered to be sensitive because a change in its value can cause a significant change in the metamodels output measurements.

Lastly, all the significant terms from all the metamodels were aggregated and analyzed to determine which terms had an overall significant impact on the MSM.

C.   ANALYSIS

This experiment was computationally intensive. Each design point took an average of 16 minutes to run, utilizing an Intel Core i7 processor with a 16 GB RAM. Extrapolating that timeline over 257 design points, this experiment took approximately 2.85 days to complete.

1.   Losses Metamodel

The first metamodel evaluated was Losses. The response surface metric was constructed by aggregating all the loss metrics output by the MSM. Specifically, this included the loss categories with Non-EAS and EAS separation codes. Each separation code has the following sub-categories: NEAS, deaths, E2O, retired, EAS, bootcamp, and other. Reference Appendix C for more information regarding MSM's output metrics.

Figure 21 shows the seven JMP statistical reports for this metamodel. This model had an excellent fit, indicated by its 0.98778 adjusted R-Square value. This is visually reinforced with the "Actual by Predicted Plot," where the model's response surface equation predicted a forecast that was within 1.3% of the actual simulated output measurements.

For our first metric, correlation, the metamodel yielded very promising information. A visual of this correlation is shown in the Prediction Profiler report; where it plots the profile for the six factors that yielded the greatest effects. From initial inspection, the six factors all had gradients that coincide with the Marine Corps' HRDP process. The two greatest factors were loss due to end of active service (EAS) and reenlisting (Reup). For EAS, the profile shows that as the rate of EAS increases, so does the quantity of Marine Corps total losses for a fiscal year, which is as expected. The profile also indicates an exponential relationship. Specifically, lower EAS loss rates have a greater sensitivity in predicting overall loss quantities.

Conversely, the Reup's loss rate had a linear relationship in the negative gradient direction. This directly aligns with the HRDP because if more Marines are staying in the Corps for a subsequent term enlistment then there are less Marine Agents that could exit the Corps. The other rates of non-EAS and bootcamp losses yielded gradients that had the correct slope and magnitude, both of which had less of an impact on the over loss quantity.

A factor that had an unanticipated significance in the Losses metamodel was the minimum time in grade (TIGmin) factor. As Figure 21 shows, this factor had both main effects and quadratic effects on the models response surface. The Prediction Profile for TIGmin reports that as the TIGmin increases there is an exponential negative gradient impact on the losses response surface. This may be an unanticipated affect that counters the rule constraints associated with the enlisted career force controls (ECFC). Specifically, a Marine Agent can not be forced to exit the Marine Corps due to being passed over for promotion too many times if they are never eligible for a promotion in the first place.

The second evaluation metric, input significance priority, is observed in the Sorted Parameter Estimates report. This report captured 15 terms that varied from main effects, quadratic effects, and two-way interactions. The column labeled "t ratio" was the measurement metric used to evaluate input significance.

Table 3, located at the end of this section, aggregates and compares the terms from all response surfaces.

Figure 21.   Losses Model Regression Analysis

Summary of Fit

RSquare	0.988499
RSquare Adj	0.98778
Root Mean Square Error	207.7148
Mean of Response	29403.93
Observations (or Sum Wgts)	256

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	889959368	59330625	1375.131
Error	240	10354908	43145.45	Prob > F
C. Total	255	900314276		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	22505.438	154.9925	145.20	<.0001*
TISmin	-33.83698	8.67502	-3.90	0.0001*
(TISmin-0.49219)*(TISmin-0.49219)	-22.74498	6.166894	-3.69	0.0003*
TIGmin	-237.9692	10.56859	-22.52	<.0001*
(TIGmin-0.99609)*(TIGmin-0.99609)	-168.1322	9.050977	-18.58	<.0001*
L.Boot	746.37632	89.83388	8.31	<.0001*
L.NEAS	2520.6538	89.43311	28.18	<.0001*
L.EAS	11002.848	89.53303	122.89	<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	-10601.46	736.1404	-14.40	<.0001*
L.Reup	-5233.99	89.68576	-58.36	<.0001*
(TISmin-0.49219)*(L.Boot-0.85081)	7.8013236	64.07839	0.12	0.9032
(TISmin-0.49219)*(L.EAS-0.8496)	-227.1354	54.84371	-4.14	<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-395.3276	76.13827	-5.19	<.0001*
(TIGmin-0.99609)*(L.EAS-0.8496)	-227.2533	82.80352	-2.74	0.0065*
(L.NEAS-0.85011)*(L.EAS-0.8496)	-4298.832	557.4738	-7.71	<.0001*
(L.EAS-0.8496)*(L.Reup-0.84937)	-2305.521	666.4464	-3.46	0.0006*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
L.EAS	11002.848	89.53303	122.89		<.0001*
L.Reup	-5233.99	89.68576	-58.36		<.0001*
L.NEAS	2520.6538	89.43311	28.18		<.0001*
TIGmin	-237.9692	10.56859	-22.52		<.0001*
(TIGmin-0.99609)*(TIGmin-0.99609)	-168.1322	9.050977	-18.58		<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	-10601.46	736.1404	-14.40		<.0001*
L.Boot	746.37632	89.83388	8.31		<.0001*
(L.NEAS-0.85011)*(L.EAS-0.8496)	-4298.832	557.4738	-7.71		<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-395.3276	76.13827	-5.19		<.0001*
(TISmin-0.49219)*(L.EAS-0.8496)	-227.1354	54.84371	-4.14		<.0001*
TISmin	-33.83698	8.67502	-3.90		0.0001*
(TISmin-0.49219)*(TISmin-0.49219)	-22.74498	6.166894	-3.69		0.0003*
(L.EAS-0.8496)*(L.Reup-0.84937)	-2305.521	666.4464	-3.46		0.0006*
(TIGmin-0.99609)*(L.EAS-0.8496)	-227.2533	82.80352	-2.74		0.0065*
(TISmin-0.49219)*(L.Boot-0.85081)	7.8013236	64.07839	0.12		0.9032

Prediction Profiler

Losses 29932.03 [29877.8, 29986.2]

TISmin	TIGmin	L.Boot	L.NEAS	L.EAS	L.Reup
0.4922	0.9961	0.85081	0.85011	0.8496	0.84937

Figure 21 Continued. Losses Model Regression Analysis

2. Gains Metamodel

The second metamodel evaluated was gains. The response surface metric was constructed by aggregating all the gain metrics output by the MSM. Specifically, this included the gain sub-categories: EAD, Occ, Rever, Cont, Broken, Deserter, and other. Reference Appendix C for more information regarding MSM's output metrics.

Figure 22 shows the seven JMP statistical reports for this metamodel. This model had an excellent fit, indicated by its 0.95829 adjusted R-Square value. This is visually reinforced with the "Actual by Predicted Plot," where the model's response surface equation predicted a forecast that was within 4.2% of the actual simulated output measurements.

For our first metric, the metamodel yielded excellent correlation with respect to the gain factors. Four out of the seven gain factors were identified as being significant. Additionally, the four selected gain factors all had positive gradients, which coincides with the HRDP. Conversely, for factors of losses were determined to be significant, where two had positive gradients and two had negative gradients. We viewed this as being positive, because even though they were determined to be significant their gradient directions offset each other. Therefore there aggregated effect had little to no impact on the metamodel. Two factors that were a surprised to have been identified as significant were TISmin and TIGmin.

An important item to reiterate is that the Gains process is separate from the Accessions process. Where the later deals predominately with new recruits entering the Marine Corps, the Gains process focuses on Marines with prior service that re-enter the Marine Corps' manpower accountability.
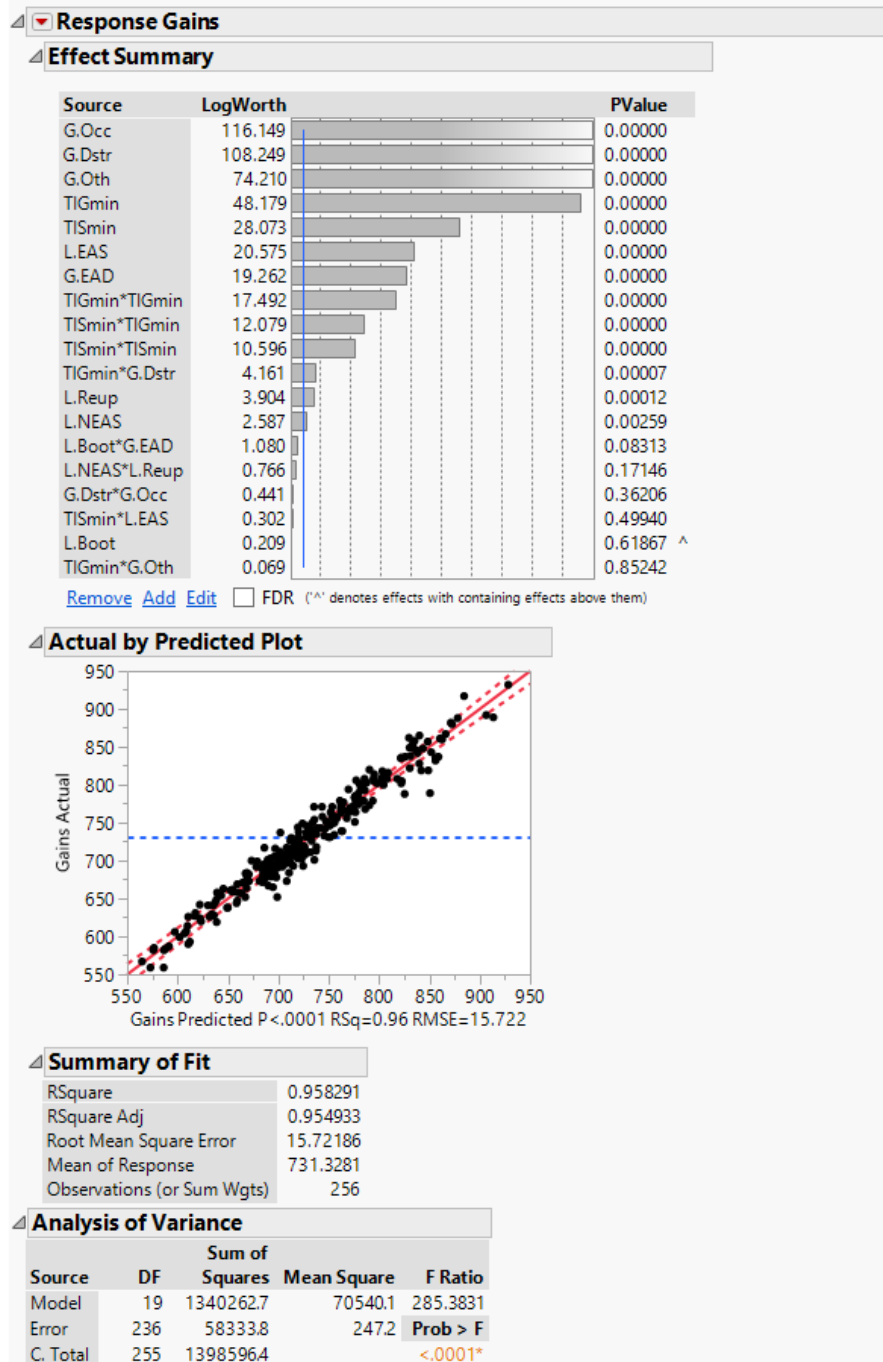
Figure 22.   Gains Model Regression Analysis

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-65.55487	16.38959	-4.00	<.0001*
TISmin	8.4038675	0.657177	12.79	<.0001*
TIGmin	15.088175	0.801316	18.83	<.0001*
L.Boot	-3.389651	6.801107	-0.50	0.6187
L.NEAS	20.61325	6.769176	3.05	0.0026*
L.EAS	70.920336	6.776908	10.46	<.0001*
L.Reup	-26.49265	6.790213	-3.90	0.0001*
G.EAD	68.393713	6.810322	10.04	<.0001*
G.Dstr	276.51739	6.770917	40.84	<.0001*
G.Oth	184.89204	6.77649	27.28	<.0001*
G.Occ	303.42149	6.810352	44.55	<.0001*
(TISmin-0.49219)*(TIGmin-0.99609)	-4.247221	0.561019	-7.57	<.0001*
(TISmin-0.49219)*(L.EAS-0.8496)	2.7941542	4.130475	0.68	0.4994
(TIGmin-0.99609)*(G.Dstr-0.84986)	24.180282	5.967729	4.05	<.0001*
(TIGmin-0.99609)*(G.Oth-0.85012)	-0.976455	5.243185	-0.19	0.8524
(L.Boot-0.85081)*(G.EAD-0.85087)	-88.10257	50.62888	-1.74	0.0831
(L.NEAS-0.85011)*(L.Reup-0.84937)	65.042312	47.41715	1.37	0.1715
(G.Dstr-0.84986)*(G.Occ-0.84909)	47.223294	51.71095	0.91	0.3621
(TISmin-0.49219)*(TISmin-0.49219)	3.2598	0.465246	7.01	<.0001*
(TIGmin-0.99609)*(TIGmin-0.99609)	6.5320147	0.690339	9.46	<.0001*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
G.Occ	303.42149	6.810352	44.55		<.0001*
G.Dstr	276.51739	6.770917	40.84		<.0001*
G.Oth	184.89204	6.77649	27.28		<.0001*
TIGmin	15.088175	0.801316	18.83		<.0001*
TISmin	8.4038675	0.657177	12.79		<.0001*
L.EAS	70.920336	6.776908	10.46		<.0001*
G.EAD	68.393713	6.810322	10.04		<.0001*
(TIGmin-0.99609)*(TIGmin-0.99609)	6.5320147	0.690339	9.46		<.0001*
(TISmin-0.49219)*(TIGmin-0.99609)	-4.247221	0.561019	-7.57		<.0001*
(TISmin-0.49219)*(TISmin-0.49219)	3.2598	0.465246	7.01		<.0001*
(TIGmin-0.99609)*(G.Dstr-0.84986)	24.180282	5.967729	4.05		<.0001*
L.Reup	-26.49265	6.790213	-3.90		0.0001*
L.NEAS	20.61325	6.769176	3.05		0.0026*
(L.Boot-0.85081)*(G.EAD-0.85087)	-88.10257	50.62888	-1.74		0.0831
(L.NEAS-0.85011)*(L.Reup-0.84937)	65.042312	47.41715	1.37		0.1715
(G.Dstr-0.84986)*(G.Occ-0.84909)	47.223294	51.71095	0.91		0.3621
(TISmin-0.49219)*(L.EAS-0.8496)	2.7941542	4.130475	0.68		0.4994
L.Boot	-3.389651	6.801107	-0.50		0.6187
(TIGmin-0.99609)*(G.Oth-0.85012)	-0.976455	5.243185	-0.19		0.8524

Prediction
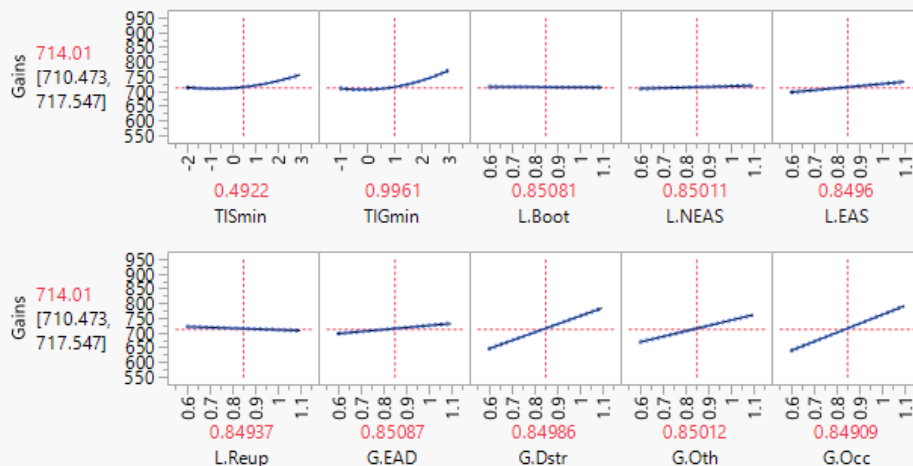
Figure 22 Continued. Gains Model Regression Analysis

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3. Promotions Metamodel

Figure 23 depicts Promotions metamodel. For the response surface, we used the direct output metric promotions in (PromIn). The Actual by Predicted Plot report showed signs of banding within the data set. Banding is a term that refers to output measures that do not have a continuous distribution. Instead, the data groups together in clusters. This implies the model hosted an aspect of discrete outcomes. To capture these discrete bands, we used JMP's functionality to create a partition tree on the data set. As anticipated, the first split identified the factor TIGmin as having a discrete impact on the model. A split categorized the factor into leaves <3 and ≥3, and was responsible for explaining 52% of the original variance in the model.

With the Partition Tree's leaves established, a standard least squares regression was re-run, this time incorporating the leaves into its regression. The recalculated regression showed a much better model fit using the hybrid regression. The adjusted R-Square value increased from 81% to 94%, justifying that this was the correct model to explain the Promotions response surface.

Focusing on the Prediction Profile report, this model showed a lot of expected behaviors. For the loss rates of retirement, NEAS, and EAS, all three had positive gradients. This fact supports the billet availability HRDP constraint in that availability must exist in order for a Marine to be promoted into a higher grade. These loss rates confirm that as the loss rate increases, that is more Marines are exiting the Corps, the more billets become available for junior Marines to promote into. Additionally, the factor TISmin yielded a profile that supported the HRDP. Specifically, if the ECFC constraints require a greater TISmin for a particular billet, that ECFC is therefore decreasing the pool of possible candidates that could be considered for promotion.
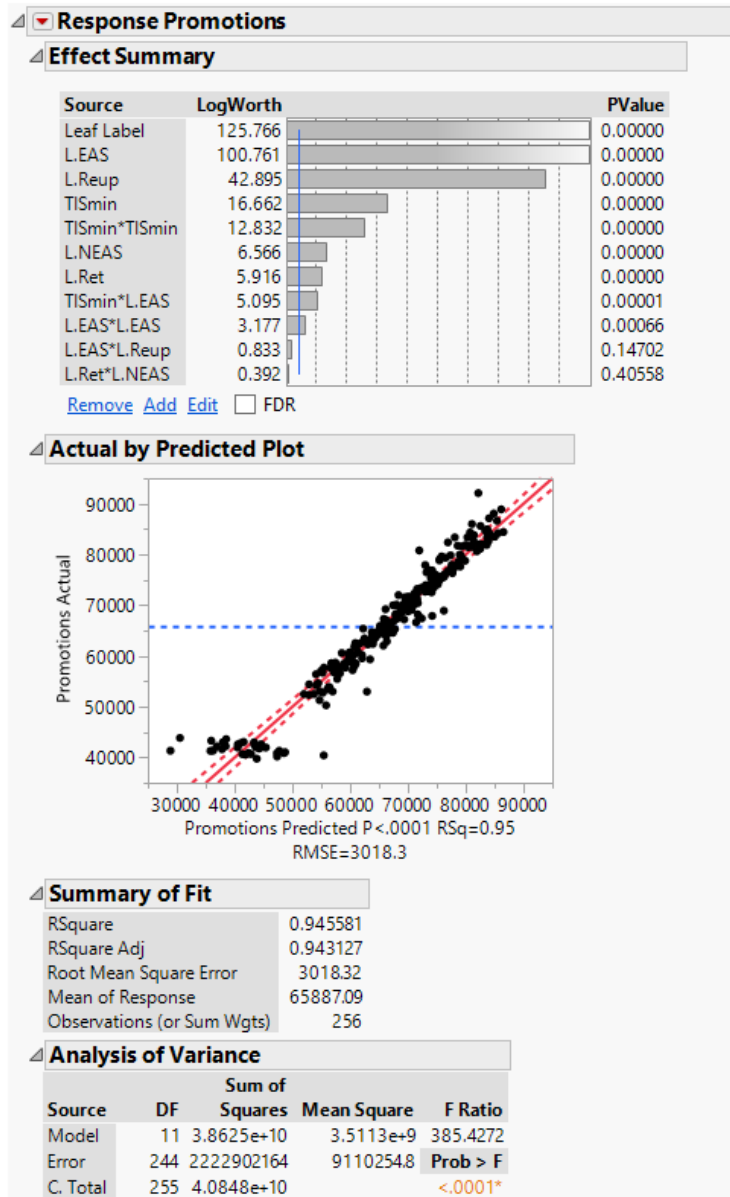
Figure 23.   Promotions Model Regression Analysis

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	25178.424	2247.606	11.20	<.0001*
Leaf Label[TIGmin<3]	14050.121	292.0981	48.10	<.0001*
TISmin	-1154.38	126.0185	-9.16	<.0001*
L.Ret	6489.7881	1303.65	4.98	<.0001*
L.NEAS	6875.724	1299.715	5.29	<.0001*
L.EAS	47861.152	1301.713	36.77	<.0001*
L.Reup	-22296.19	1303.962	-17.10	<.0001*
(TISmin-0.49219)*(L.EAS-0.8496)	-3619.702	793.4596	-4.56	<.0001*
(L.Ret-0.85035)*(L.NEAS-0.85011)	-10193.43	12234.94	-0.83	0.4056
(L.EAS-0.8496)*(L.Reup-0.84937)	-17311.74	11899.92	-1.45	0.1470
(TISmin-0.49219)*(TISmin-0.49219)	-704.5717	89.96433	-7.83	<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	-36479.29	10579.58	-3.45	0.0007*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
Leaf Label[TIGmin<3]	14050.121	292.0981	48.10		<.0001*
L.EAS	47861.152	1301.713	36.77		<.0001*
L.Reup	-22296.19	1303.962	-17.10		<.0001*
TISmin	-1154.38	126.0185	-9.16		<.0001*
(TISmin-0.49219)*(TISmin-0.49219)	-704.5717	89.96433	-7.83		<.0001*
L.NEAS	6875.724	1299.715	5.29		<.0001*
L.Ret	6489.7881	1303.65	4.98		<.0001*
(TISmin-0.49219)*(L.EAS-0.8496)	-3619.702	793.4596	-4.56		<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	-36479.29	10579.58	-3.45		0.0007*
(L.EAS-0.8496)*(L.Reup-0.84937)	-17311.74	11899.92	-1.45		0.1470
(L.Ret-0.85035)*(L.NEAS-0.85011)	-10193.43	12234.94	-0.83		0.4056

Figure 23 Continued. Promotions Model Regression Analysis

4. LatMoves Metamodel

Figure 24 depicts lateral moves (LatMoves) metamodel. For the response surface, we used the direct output metric lateral moves in (LMIn). The LatMoves model returned the second best Summary of Fit report characteristics when compared to the other metamodels. Specifically, it calculated an impressive adjusted RSquare value of 99%, meaning an almost exact fit between the metamodel and the existing data.

With respect to correlation and gradients, the LatMoves metamodel closely mimicked the Promotions metamodel. This makes sense because while promotions analysis is concerned with the vertical accession through the MOS-

Grade state graph network, LatMoves is concerned with the horizontal transitions. In both cases, vacancies must exist to facilitate the need for a Marine to LatMove into that identified MOS.

With respect to term significance, loss rates once again dominated the metamodel. This again reinforces the fact that the MSM is built around the billet vacancy constraint; that vacancies must exist in order to allow Marine Agents to move around within the MOS-Grade state graph network.

Figure 24.   LatMoves Model Regression Analysis

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	18	2231871.1	123993	1527.231
Error	237	19241.6	81	Prob > F
C. Total	255	2251112.7		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	190.41111	8.842652	21.53	<.0001*
TIGmin	0.2287258	0.458333	0.50	0.6182
L.Ret	110.21021	3.884304	28.37	<.0001*
L.NEAS	135.16122	3.879582	34.84	<.0001*
L.e2o	39.957102	3.884513	10.29	<.0001*
L.EAS	518.03018	3.883523	133.39	<.0001*
L.Reup	-328.6002	3.889821	-84.48	<.0001*
G.Dstr	-0.024025	3.880185	-0.01	0.9951
G.Occ	-18.36313	3.900388	-4.71	<.0001*
(TIGmin-0.99609)*(L.Ret-0.85035)	21.866344	3.392504	6.45	<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	13.31528	3.497996	3.81	0.0002*
(TIGmin-0.99609)*(L.EAS-0.8496)	17.382537	3.692894	4.71	<.0001*
(L.Ret-0.85035)*(L.NEAS-0.85011)	22.141672	38.47048	0.58	0.5655
(L.Ret-0.85035)*(L.Reup-0.84937)	-77.11275	26.60797	-2.90	0.0041*
(L.Ret-0.85035)*(G.Dstr-0.84986)	90.320057	26.12011	3.46	0.0006*
(L.e2o-0.84954)*(G.Occ-0.84909)	31.709231	29.58031	1.07	0.2848
(L.EAS-0.8496)*(L.Reup-0.84937)	-359.4333	35.96777	-9.99	<.0001*
(TIGmin-0.99609)*(TIGmin-0.99609)	1.1582711	0.395816	2.93	0.0038*
(L.Reup-0.84937)*(L.Reup-0.84937)	136.10863	31.36948	4.34	<.0001*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
L.EAS	518.03018	3.883523	133.39		<.0001*
L.Reup	-328.6002	3.889821	-84.48		<.0001*
L.NEAS	135.16122	3.879582	34.84		<.0001*
L.Ret	110.21021	3.884304	28.37		<.0001*
L.e2o	39.957102	3.884513	10.29		<.0001*
(L.EAS-0.8496)*(L.Reup-0.84937)	-359.4333	35.96777	-9.99		<.0001*
(TIGmin-0.99609)*(L.Ret-0.85035)	21.866344	3.392504	6.45		<.0001*
G.Occ	-18.36313	3.900388	-4.71		<.0001*
(TIGmin-0.99609)*(L.EAS-0.8496)	17.382537	3.692894	4.71		<.0001*
(L.Reup-0.84937)*(L.Reup-0.84937)	136.10863	31.36948	4.34		<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	13.31528	3.497996	3.81		0.0002*
(L.Ret-0.85035)*(G.Dstr-0.84986)	90.320057	26.12011	3.46		0.0006*
(TIGmin-0.99609)*(TIGmin-0.99609)	1.1582711	0.395816	2.93		0.0038*
(L.Ret-0.85035)*(L.Reup-0.84937)	-77.11275	26.60797	-2.90		0.0041*
(L.e2o-0.84954)*(G.Occ-0.84909)	31.709231	29.58031	1.07		0.2848
(L.Ret-0.85035)*(L.NEAS-0.85011)	22.141672	38.47048	0.58		0.5655
TIGmin	0.2287258	0.458333	0.50		0.6182
G.Dstr	-0.024025	3.880185	-0.01		0.9951

Prediction Profiler

Figure 24 Continued. LatMoves Model Regression Analysis

5.   End Strength Metamodel

Figure 25 depicts the End Strength metamodel. For the response surface, we used the direct output metric "End"; refer to Appendix C to view all MSM outputs. The End Strength model yielded the worst Summary of Fit report characteristics. However, this was expected. Let us first explain the reports produced by JMP and then we will justify why it was expected.

From the initial standard least squares regression, banding was identified which suggested a factor was exhibiting discrete impact properties. This was confirmed with a Partition Tree. Specifically, the factor TIGmin was again identified in having the same categorical impacts of <3 and $\geq$3 leaf values. Applying a singular split explained 86% of the variance within the model.

With the Partition Tree's leaves established, a standard least squares regression was re-run, this time incorporating the leaves into its regression. The recalculated regression showed a much better model fit using the hybrid regression. The Adjusted RSquared value increased from 72% to 92%, justifying that this was the correct metamodel to explain the End Strength response surface.
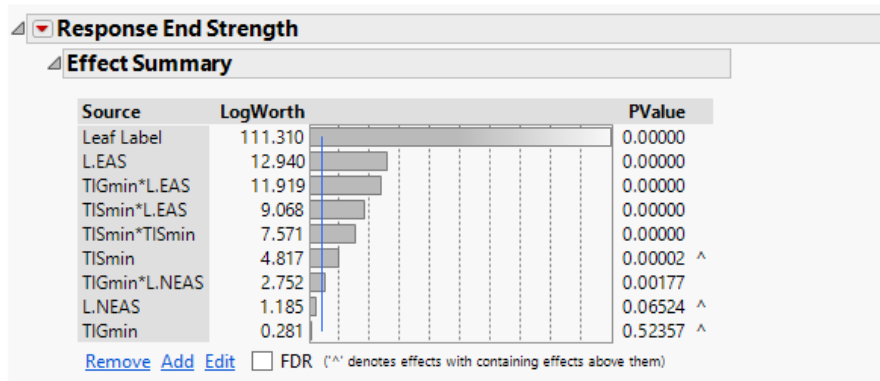
Figure 25.   End Strength Model Regression Analysis

Actual by Predicted Plot

End Strength Predicted P<.0001 RSq=0.93
RMSE=2066

Summary of Fit

RSquare	0.925654
RSquare Adj	0.922934
Root Mean Square Error	2066.011
Mean of Response	151813.6
Observations (or Sum Wgts)	256

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	1.3074e+10	1.4526e+9	340.3178
Error	246	1050026781	4268401.5	Prob > F
C. Total	255	1.4124e+10		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	152526.75	1136.465	134.21	<.0001*
Leaf Label[TIGmin<3]	10237.781	249.4606	41.04	<.0001*
TISmin	-380.7795	86.28014	-4.41	<.0001*
TIGmin	-85.41791	133.7238	-0.64	0.5236
L.NEAS	-1647.564	889.6798	-1.85	0.0652
L.EAS	-7012.549	891.3958	-7.87	<.0001*
(TISmin-0.49219)*(L.EAS-0.8496)	-3465.878	542.9467	-6.38	<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-2350.852	743.7881	-3.16	0.0018*
(TIGmin-0.99609)*(L.EAS-0.8496)	-6115.929	816.1616	-7.49	<.0001*
(TISmin-0.49219)*(TISmin-0.49219)	-339.8115	59.1365	-5.75	<.0001*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
Leaf Label[TIGmin<3]	10237.781	249.4606	41.04		<.0001*
L.EAS	-7012.549	891.3958	-7.87		<.0001*
(TIGmin-0.99609)*(L.EAS-0.8496)	-6115.929	816.1616	-7.49		<.0001*
(TISmin-0.49219)*(L.EAS-0.8496)	-3465.878	542.9467	-6.38		<.0001*
(TISmin-0.49219)*(TISmin-0.49219)	-339.8115	59.1365	-5.75		<.0001*
TISmin	-380.7795	86.28014	-4.41		<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-2350.852	743.7881	-3.16		0.0018*
L.NEAS	-1647.564	889.6798	-1.85		0.0652
TIGmin	-85.41791	133.7238	-0.64		0.5236

Prediction Profiler

Figure 25 Continued. End Strength Model Regression Analysis

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As previously stated, the model's poor fit characteristics were expected. This is due to the constraint applied by the MSM that vacancies must exist to get Marine Agents to move within the model. However, the overall quantity of vacancies is capped by the input GAR force structure. For this experiment, the same GAR structure progression was used for every DOE design point. This ensured that every design point simulation run had a fourth-year GAR end strength input value of 154,836 personnel.

Figure 26 shows the End Strength output measurement's distribution. Specifically it shows a histogram of End Strength values for each of the 256 design points, as well as a statistical summary for that histogram. The produced histogram visually shows that an overwhelmingly majority of the 256 design points yielded End Strength calculations that were tightly coupled next to the GAR's fourth forecasted year. Secondly, the Summary Statistics report shows the statistical mean calculated from this distribution, and the respective 95% confidence interval that is tightly coupled around the mean.

To summarize, these facts prove that the MSM was built to align with future GARs. Therefore, GARs are without a doubt the most crucial and significant input for the simulation. It also yields warning that the data output metrics are directly dependent on the GAR. Meaning the manpower forecasts produced from adjusting any of the any internal constraints, like ECFCs, are only accurate for the specific GAR it ran its simulation off of.

End Strength		

Quantiles			Summary Statistics	
100.0%	maximum	154836	Mean	151813.63
99.5%		154836	Std Dev	7442.2069
97.5%		154836	Std Err Mean	465.13793
90.0%		154836	Upper 95% Mea	152729.63
75.0%	quartile	154835	Lower 95% Mean	150897.63
50.0%	median	154835	N	256
25.0%	quartile	154835		
10.0%		138193.9		
2.5%		127421.825		
0.5%		123813.565		
0.0%	minimum	123526		
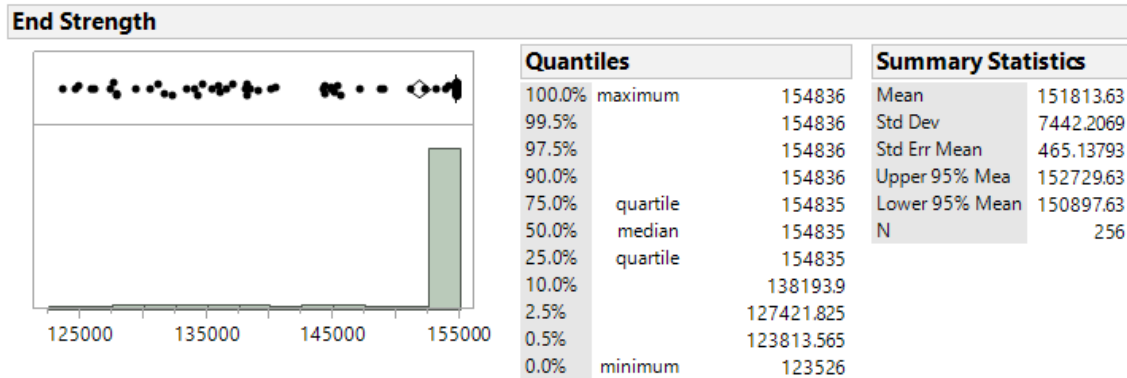
Figure 26.   DOE End Strength Distribution Analysis

6.   P2T2 Metamodel

Figure 27 depicts the Patients, Prisoners, Transients, and Trainees (P2T2) metamodel. For the response surface, we used the direct output metric "P2T2"; refer to Appendix C to view all MSM outputs. Immediate signs with the P2T2 model suggested that discrete factors were having an impact on its response, so a partition tree was used to identify the data bandings that were occurring. Once again TIGmin was identified as having a discrete impact on the model. A split categorized the factor into leaves <3 and ≥3, and was responsible for explaining 86% of the original variance in the model.

With the Partition Tree's leaves established, a standard least squares regression was re-run, this time incorporating the leaves into its regression. The recalculated regression showed a much better model fit using the hybrid regression. The adjusted RSquare value increased from 74% to 95%, justifying that this was the correct metamodel to explain the Gains response surface.

It was originally anticipated that the input significance priority would have been more equally distributed across a larger variety of factor terms. As explained in Chapter III, the P2T2 is calculated from the instantiation of a Marine Agent being selected for a LatMove. Therefore, if the quantity of LatMoves increases, so should the quantity of P2T2. Some of this does show through in Figure 27 with respect to the positive correlation value for EAS and the negative

correlation value with Reenlistment (Reup). Specifically, as these two factor terms increase in positive and negative values, respectively, more vacancies would open up in MOS-Grade states which therefore would give more Marines the opportunity to LatMove into a new MOS.
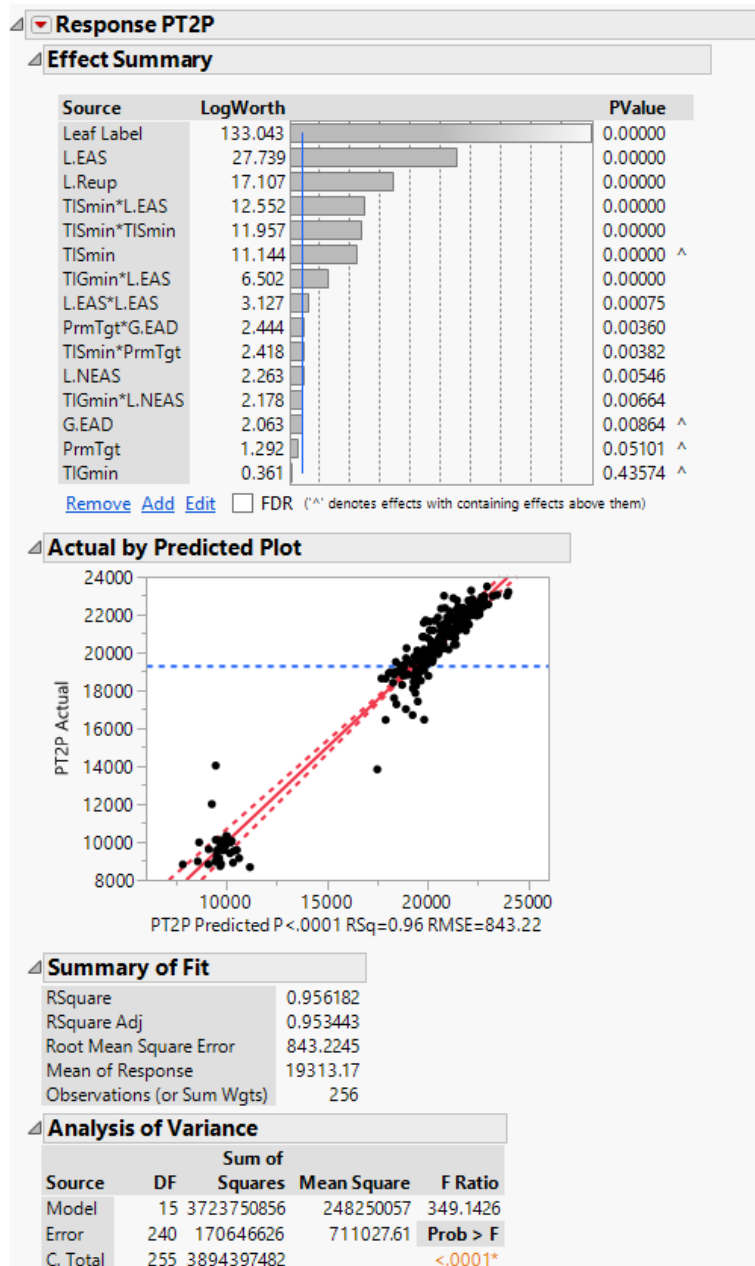
Figure 27.   P2T2 Model Regression Analysis

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	13219.674	644.8322	20.50	<.0001*
Leaf Label[TIGmin<3]	5503.3663	104.5987	52.61	<.0001*
TISmin	-254.1741	35.24504	-7.21	<.0001*
TIGmin	-43.06767	55.1642	-0.78	0.4357
PrmTgt	59.448439	30.31253	1.96	0.0510
L.NEAS	1018.2579	363.1178	2.80	0.0055*
L.EAS	4605.9653	363.9161	12.66	<.0001*
L.Reup	-3397.674	364.519	-9.32	<.0001*
G.EAD	968.27254	365.7014	2.65	0.0086*
(TISmin-0.49219)*(PrmTgt-0.99414)	52.293437	17.9016	2.92	0.0038*
(TISmin-0.49219)*(L.EAS-0.8496)	-1750.078	226.1872	-7.74	<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-832.6004	304.0397	-2.74	0.0066*
(TIGmin-0.99609)*(L.EAS-0.8496)	-1755.609	333.5943	-5.26	<.0001*
(PrmTgt-0.99414)*(G.EAD-0.85087)	-616.5902	209.7159	-2.94	0.0036*
(TISmin-0.49219)*(TISmin-0.49219)	-188.2584	25.0417	-7.52	<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	-10247.39	2999.882	-3.42	0.0007*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
Leaf Label[TIGmin<3]	5503.3663	104.5987	52.61		<.0001*
L.EAS	4605.9653	363.9161	12.66		<.0001*
L.Reup	-3397.674	364.519	-9.32		<.0001*
(TISmin-0.49219)*(L.EAS-0.8496)	-1750.078	226.1872	-7.74		<.0001*
(TISmin-0.49219)*(TISmin-0.49219)	-188.2584	25.0417	-7.52		<.0001*
TISmin	-254.1741	35.24504	-7.21		<.0001*
(TIGmin-0.99609)*(L.EAS-0.8496)	-1755.609	333.5943	-5.26		<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	-10247.39	2999.882	-3.42		0.0007*
(PrmTgt-0.99414)*(G.EAD-0.85087)	-616.5902	209.7159	-2.94		0.0036*
(TISmin-0.49219)*(PrmTgt-0.99414)	52.293437	17.9016	2.92		0.0038*
L.NEAS	1018.2579	363.1178	2.80		0.0055*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-832.6004	304.0397	-2.74		0.0066*
G.EAD	968.27254	365.7014	2.65		0.0086*
PrmTgt	59.448439	30.31253	1.96		0.0510
TIGmin	-43.06767	55.1642	-0.78		0.4357

Prediction Profiler

Figure 27 Continued. P2T2 Model Regression Analysis

7.   Retention Metamodel

Figure 28 depicts Retention metamodel. The response surface metric was constructed by aggregating all the "In-Year," "Out-of-Year," and "Not Accounted

for" subcategories of MSM's retention metrics. Reference Appendix C for more information regarding MSM's output metrics.

The Retention model returned the best Summary of Fit characteristics of any metamodel. Specifically, it boasted an impressive adjusted RSquare value of 99.9%. Additionally, the significant factor terms had correlation signs that aligned with the HRDP process. Specifically, the EAS loss rate had a predominate effect on the response surface of the model, which is expected because if Marines reach their EAS and leave the Marine Corps there will be a dramatic drop in the candidate population that could reenlist.

Response Retain Sum

Effect Summary

Source	LogWorth		PValue
L.EAS	357.890		0.00000
L.Reup	171.804		0.00000
L.NEAS	163.437		0.00000
L.EAS*L.EAS	82.920		0.00000
L.NEAS*L.EAS	53.510		0.00000
L.Ret	40.250		0.00000
L.EAS*L.Reup	30.652		0.00000
TIGmin	28.682		0.00000
TIGmin*TIGmin	20.895		0.00000
TIGmin*L.EAS	10.568		0.00000
L.Reup*L.Reup	8.509		0.00000
TIGmin*L.NEAS	8.243		0.00000
L.Ret*L.EAS	5.882		0.00000
L.Oth	4.104		0.00008
L.Dth	1.561		0.02748
L.Dth*L.Oth	0.567		0.27091
TIGmin*L.Ret	0.132		0.73817

Remove Add Edit ☐ FDR

Summary of Fit

RSquare	0.999045
RSquare Adj	0.998976
Root Mean Square Error	139.6945
Mean of Response	21795.02
Observations (or Sum Wgts)	256

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	17	4857003008	285706059	14640.66
Error	238	4644464.27	19514.556	Prob > F
C. Total	255	4861647472		<.0001*

Figure 28.   Reenlistment Model Regression Analysis

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	55366.393	127.9425	432.74	<.0001*
TIGmin	-92.08955	7.107783	-12.96	<.0001*
L.Ret	-987.9805	60.22097	-16.41	<.0001*
L.NEAS	-4357.312	60.14767	-72.44	<.0001*
L.Dth	-134.0248	60.41711	-2.22	0.0275*
L.Oth	-243.1516	60.51322	-4.02	<.0001*
L.EAS	-29247.59	60.21271	-485.7	<.0001*
L.Reup	-4753.564	60.31207	-78.82	<.0001*
(TIGmin-0.99609)*(L.Ret-0.85035)	-17.45813	52.16481	-0.33	0.7382
(TIGmin-0.99609)*(L.NEAS-0.85011)	-322.4078	53.33114	-6.05	<.0001*
(TIGmin-0.99609)*(L.EAS-0.8496)	-394.9032	56.47216	-6.99	<.0001*
(L.Ret-0.85035)*(L.EAS-0.8496)	2166.4884	436.3943	4.96	<.0001*
(L.NEAS-0.85011)*(L.EAS-0.8496)	7712.1444	377.6616	20.42	<.0001*
(L.Dth-0.84918)*(L.Oth-0.84905)	-486.0133	440.4186	-1.10	0.2709
(L.EAS-0.8496)*(L.Reup-0.84937)	6160.3322	454.7131	13.55	<.0001*
(TIGmin-0.99609)*(TIGmin-0.99609)	-65.03441	6.159786	-10.56	<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	14614.132	482.3181	30.30	<.0001*
(L.Reup-0.84937)*(L.Reup-0.84937)	2973.5801	482.8362	6.16	<.0001*

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
L.EAS	-29247.59	60.21271	-485.7		<.0001*
L.Reup	-4753.564	60.31207	-78.82		<.0001*
L.NEAS	-4357.312	60.14767	-72.44		<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	14614.132	482.3181	30.30		<.0001*
(L.NEAS-0.85011)*(L.EAS-0.8496)	7712.1444	377.6616	20.42		<.0001*
L.Ret	-987.9805	60.22097	-16.41		<.0001*
(L.EAS-0.8496)*(L.Reup-0.84937)	6160.3322	454.7131	13.55		<.0001*
TIGmin	-92.08955	7.107783	-12.96		<.0001*
(TIGmin-0.99609)*(TIGmin-0.99609)	-65.03441	6.159786	-10.56		<.0001*
(TIGmin-0.99609)*(L.EAS-0.8496)	-394.9032	56.47216	-6.99		<.0001*
(L.Reup-0.84937)*(L.Reup-0.84937)	2973.5801	482.8362	6.16		<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-322.4078	53.33114	-6.05		<.0001*
(L.Ret-0.85035)*(L.EAS-0.8496)	2166.4884	436.3943	4.96		<.0001*
L.Oth	-243.1516	60.51322	-4.02		<.0001*
L.Dth	-134.0248	60.41711	-2.22		0.0275*
(L.Dth-0.84918)*(L.Oth-0.84905)	-486.0133	440.4186	-1.10		0.2709
(TIGmin-0.99609)*(L.Ret-0.85035)	-17.45813	52.16481	-0.33		0.7382

Prediction Profiler

Figure 28 Continued. Reenlistment Model Regression Analysis

8.   Accessions Metamodel

Figure 29 depicts Accessions metamodel. For the response surface, we used the direct output metric non-prior service (NPS) accessions. Immediate signs with the Accessions metamodel suggested that discrete factors were having an impact on its response, so a partition tree was used to identify the data bandings that were occurring. Once again TIGmin was identified as having a discrete impact on the model. A split categorized the factor into leaves <3 and $\geq$ 3, and was responsible for explaining 85% of the original variance in the model.

With the Partition Tree's leaves established, a standard least squares regression was re-run, this time incorporating the leaves into its regression. The recalculated regression showed a much better model fit using the hybrid regression. The adjusted RSquare value increased from 75% to 95%, justifying that this was the correct metamodel to explain the Gains response surface.
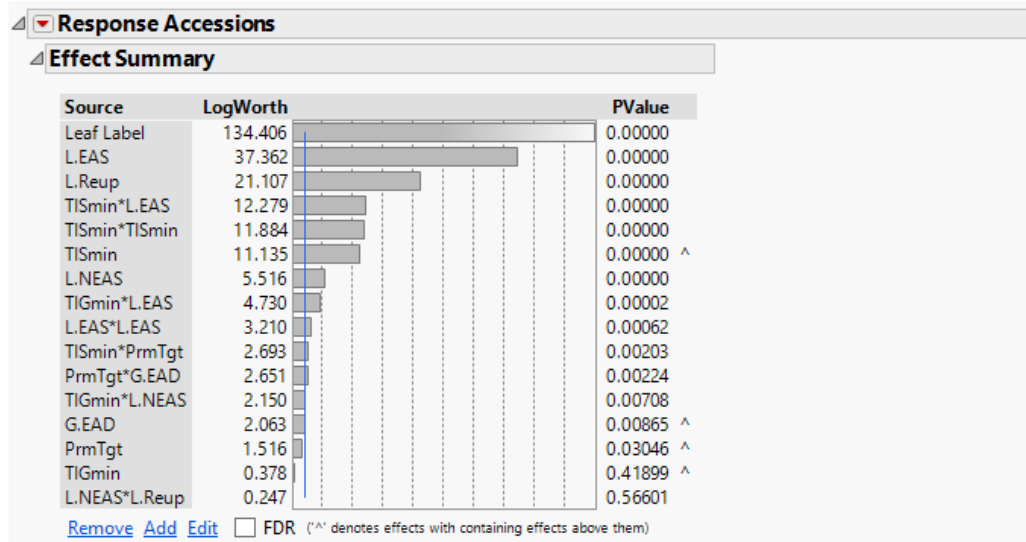
Figure 29.   Accessions Model Regression Analysis

Actual by Predicted Plot

Accessions Predicted P<.0001 RSq=0.96
RMSE=1133.5
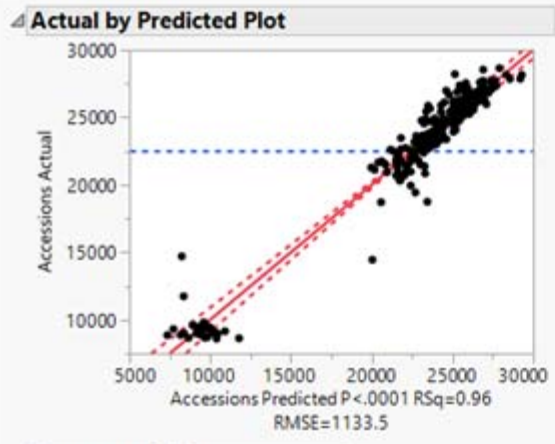
Summary of Fit

RSquare	0.958568
RSquare Adj	0.955794
Root Mean Square Error	1133.465
Mean of Response	2253631
Observations (or Sum Wgts)	256

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	16	7103966349	443997897	345.5925
Error	239	307053798	1284743.9	Prob > F
C. Total	255	7411020147		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	12759.794	866.9994	14.72	<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	12759.794	866.9994	14.72	<.0001*
Leaf Label[TIGmin<3]	7542.0641	140.8028	53.56	<.0001*
TISmin	-341.5878	47.37688	-7.21	<.0001*
TIGmin	-60.0739	74.20471	-0.81	0.4190
PrmTgt	88.701934	40.74623	2.18	0.0305*
L.NEAS	2333.6804	488.1127	4.78	<.0001*
L.EAS	7598.8783	489.1799	15.53	<.0001*
L.Reup	-5203.977	489.9945	-10.62	<.0001*
G.EAD	1301.4991	491.5779	2.65	0.0086*
(TISmin-0.49219)*(PrmTgt-0.99414)	75.096502	24.0656	3.12	0.0020*
(TISmin-0.49219)*(L.EAS-0.8496)	-2323.951	304.2219	-7.64	<.0001*
(TIGmin-0.99609)*(L.NEAS-0.85011)	-1117.865	411.514	-2.72	0.0071*
(TIGmin-0.99609)*(L.EAS-0.8496)	-1990.744	455.6835	-4.37	<.0001*
(PrmTgt-0.99414)*(G.EAD-0.85087)	-871.7611	282.081	-3.09	0.0022*
(L.NEAS-0.85011)*(L.Reup-0.84937)	1977.4749	3440.65	0.57	0.5660
(TISmin-0.49219)*(TISmin-0.49219)	-252.6826	33.72508	-7.49	<.0001*
(L.EAS-0.8496)*(L.EAS-0.8496)	-13994.78	4032.646	-3.47	0.0006*

Figure 29 Continued. Accessions Model Regression Analysis

Figure 29 Continued. Accessions Model Regression Analysis

9.　　　Effect Significance

The purpose of this section was to analyze the significant terms calculated by each metamodel. The metric for measuring this was the calculated "t Ratio," which is viewed in the Sorted Parameter Estimates report. "t Ratio" is the ratio of the estimate when compared to its standard error ("Estimates," n.d., Sorted Estimates section). The final product of this analysis was Table 4.

While it can be positive or negative in order to identify the term's gradient direction, our analysis chose to focus on overall effect significance vice gradient. To accomplish this, we took the absolute value of each term's value, aggregated and averaged that term, where blank cells received a value of zero, and then sorted the terms in descending order. Blank cells in Table 4 represent instances

where that term was not identified as being significant for that particular metamodel. Main effects factors are bolded for easy viewing.

Table 4.   Aggregated Effects and their Priority of Significance

Input	Losses	Gains	Promotions	LatMoves	End Strength	P2T2	Re-Enlist	Accessions	Absolute Value Avg t Ratio
L.EAS	122.89	10.46	36.77	133.39	-7.87	12.66	-485.7	15.53	103.16
L.Reup	-58.36	-3.9	-17.1	-84.48		-9.32	-78.82	-10.62	32.83
L.NEAS	28.18	3.05	5.29	34.84	-1.85	2.8	-72.44	4.78	19.15
TIGmin	-22.52	18.83			-0.64	-0.78	-12.96	-0.81	7.07
L.EAS*L.EAS	-14.4		-3.45			-3.42	30.3	-3.47	6.88
L.Ret			4.98	28.37			-16.41		6.22
G.Occ		44.55		-4.71					6.16
TISmin	-3.9	12.79	-9.16		-4.41	-7.21		-7.21	5.59
TIGmin*TIGmin	-18.58	9.46		2.93			-10.56		5.19
G.Dstr		40.84							5.11
TISmin*TISmin	-3.69	7.01	-7.83		-5.75	-7.52		-7.49	4.91
TIGmin*L.EAS	-2.74			4.71	-7.49	-5.26	-6.99	-4.37	3.95
TISmin*L.EAS	-4.41	0.68	-4.56		-6.38	-7.74		-7.64	3.93
L.EAS*L.Reup	-3.46		-1.45	-9.99			13.55		3.56
L.NEAS*L.EAS	-7.71						20.42		3.52
G.Oth		27.28							3.41
TIGmin*L.NEAS	-5.19			3.81	-3.16	-2.74	-6.05	-2.72	2.96
G.EAD		10.04				2.65		2.65	1.92
L.Reup*L.Reup				4.34			6.16		1.31
L.e2o				10.29					1.29
L.Boot	8.31	-0.5							1.10
Tismin*TIGmin		-7.57							0.95
TIGmin*L.Ret				6.45					0.81
Tismin*PrmTgt						2.92		3.12	0.76
PrmTgt*G.EAD						-2.94		-3.09	0.75
L.Ret*L.EAS							4.96		0.62
PrmTgt						1.96		2.18	0.52
TIGmin*G.Dstr		4.05							0.51
L.Other							-4.02		0.50
L.Ret*G.Dstr				3.46					0.43
L.Ret*L.Reup				-2.9					0.36
L.Death							-2.22		0.28
L.NEAS*L.Reup		1.37						0.57	0.24
L.Boot*G.EAD		-1.74							0.22
L.e2o*G.Occ				1.07					0.13
G.Dstr*G.Occ		0.91							0.11
L.Ret*L.NEAS			-0.83						0.10
TIGmin*G.Oth		-0.19							0.02
TISmin*L.Boot	0.12								0.02

10.   Database Pull Inputs

During the course of this experiment, a pattern emerged with respect to the database pulls from Total Force Data Warehouse (TFDW), invoked by MSM's source code, and how they were utilized as inputs for the MSM. While we were writing and debugging our test-main Java class, the class that would run the DOE experiment, it was observed that the TFDW data pull "Reenlistments" had zero effect on any of the output measurements. Examining this further, it was determined that while MSM pulls "Reenlistments" data from TFDW and stores it as an object within the MSM, the MSM never again references or invokes this data. While the level of significance for the other three database pulls was not examined nor determined, due to how this experiment was setup and run, the after-action knowledge gained for this insignificant impact was worth annotating in the analysis of the DOE experiment

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V. MSM VALIDATION

This chapter examines the accuracy of the model with respect to its ability to forecast into the future. To complete this evaluation, historical data from the past 12 fiscal years was obtained. This data served two key requirements in order to complete the validation study. First, a specific fiscal year's data served as the various inputs that are required to initialize the MSM. As discussed in Chapter III, this required extracting a specific fiscal year's GAR force structure, initial inventory, all the reference inputs that specify the manpower pyramid transition rates, and ECFCs.

Secondly, the data was used to compare MSM's output measurements against the Marine Corps' historic manpower quantities. This comparison was made at each fiscal year iteration within the MSM. It was decided to have each simulation forecast out to five years per simulation run as the majority of enlisted contracts conclude by the five-year mark, and therefore would get one complete cycle of Marine Agents through the program (Garrick, 2014). As Figure 30 shows, each simulation run was iterated such that the previous run's first forecasted year became the MSM's inputs.

The metric for measurement during this validation was the computed relative error for the various categories of each forecasted year. Equation (6) depicts the formula for calculating this error were $\bar{X}$ serves as the measured mean for a particular category, and τ is its actual historical value (Law & Kelton, 2000).

$$\gamma = \frac{\left(\bar{X} - \tau\right)}{\tau} \tag{6}$$

Using relative error allowed for the formula to naturally normalize a data set to its respective fiscal year target. This was crucial as the numerous manpower historic quantities naturally fluctuate year to year. The equation also standardized the calculations; negative calculations indicated the MSM

underestimated that metric while positive calculations indicated the MSM overestimated.
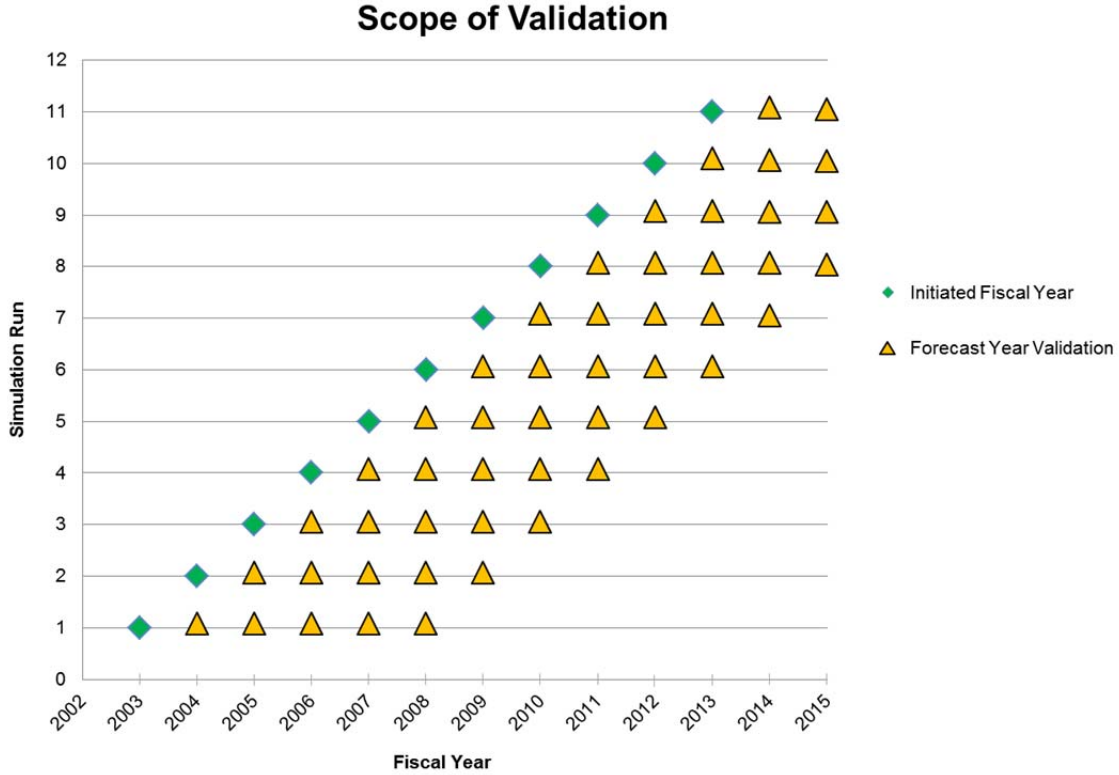
Figure 30.   Scope of Validation

It was decided to seed the Mersenne Twister's Random number Generator with the sequence 224. Seeding the random number generator ensures that each simulation will follow the exact same random number progression. This action removes any dependence on the random number generator, and therefore enabled us to compare MSM's forecasted years per simulation run amongst each other. To ensure an appropriate distribution of output results, 30 repetitions were conducted per each simulation run.

A.   UNCONTROLLABLE FACTORS

It is critical to understand that this validation experiment measured how the MSM deviates from historical manpower progressions. However, the derived accuracy of this validation experiment is based off of the assumption that the historical manpower progression is constant, and therefore is controllable. This unfortunately does not marry up ideally with Marine Corps' history. It should come to no surprise that numerous uncontrollable factors have occurred throughout out the range of the fiscal years that were selected for this validation. Events such as Operating Iraqi Freedom (OIF), Operating Enduring Freedom (OEF), sequestration, drawing down the Department of Defense's manpower force structure, as well as natural changes in command and leadership all influence the direction the Marine Corps intends to go and the manpower required to accomplish it. This is being stated because the MSM's ability to accurately forecast is dependent on the future inventory structure GARs that serve as its inputs, as well as the transition rates it uses for estimating Marine Agent movement. Therefore, while it is reasonable to assume that each successive forecasted year is anticipated to experience larger relative error, external real-life events have impacted the Marine Corps to alter its previously planned manpower force structure.

B.   SOURCE CODE CONSTRAINTS

During the course of the validation experiment, we identified that the retention zones that are hard coded into the MSM's source code do not align exactly with current Marine Corps policy. Specifically, MSM defines these zones as:

- Zone A: less than 5 years of service
- Zone B: less than 9 years of service.
- Zone C: less than 13 years of service.
- Zone D: less than 17 years of service.
- Senior Enlisted Zone: greater than or equal to 20 years of service.

Current Marine Corps policy defines these zones as:

- Zone A: less than 6 years of service

- Zone B: less than 11 years of service.

- Zone C: less than 15 years of service.

- Zone D: less than 19 years of service.

- Senior Enlisted Zone: greater than or equal to 19 years of service.

Because we were unable to determine if these were tuning parameters that were set by the developer to manually adjust the MSM in hopes of producing more accurate results, we decided to leave these as is in order to effectively evaluate the MSM program that is currently being used by M&RA.

C.   RESULTS

Maintaining consistency with Chapter IV's Design of Experiment, the following categories were examined: aggregated losses, aggregated gains, promotions to the effect of drilling down into promoting-to grade data fields, end strength, and retention to the effect of drilling down into retention zone data fields. To normalize how each validation result was graphed, common procedures were enacted. Each simulation run was labeled by the first year it forecasted. For example if the user loaded 2005's inventory and transition rate data into the MSM, with 2006's GAR inventory structure and Enlisted Career Force Controls, fiscal year 2006 would be the first forecasted year and therefore would also be the label name for that particular simulation run. When plotting each categories relative error results, it was decided to arrange the data such that numerical forecasted years served as the independent variable on the y-axis and the relative errors served as the dependent variable on the x-axis. This data arrangement facilitated the ability to overlay the simulation runs in order to determine common patterns of progression within the MSM.

Figure 31 through Figure 51 are the relative error graphs for each validation category. To reduce the clutter of the graphs, as well as focus on time

periods that are less centered on OIF and OEF, the graphs show only simulation runs stating at fiscal year 2009 and beyond. The full relative error results can be viewed in matrix form within Appendix G.
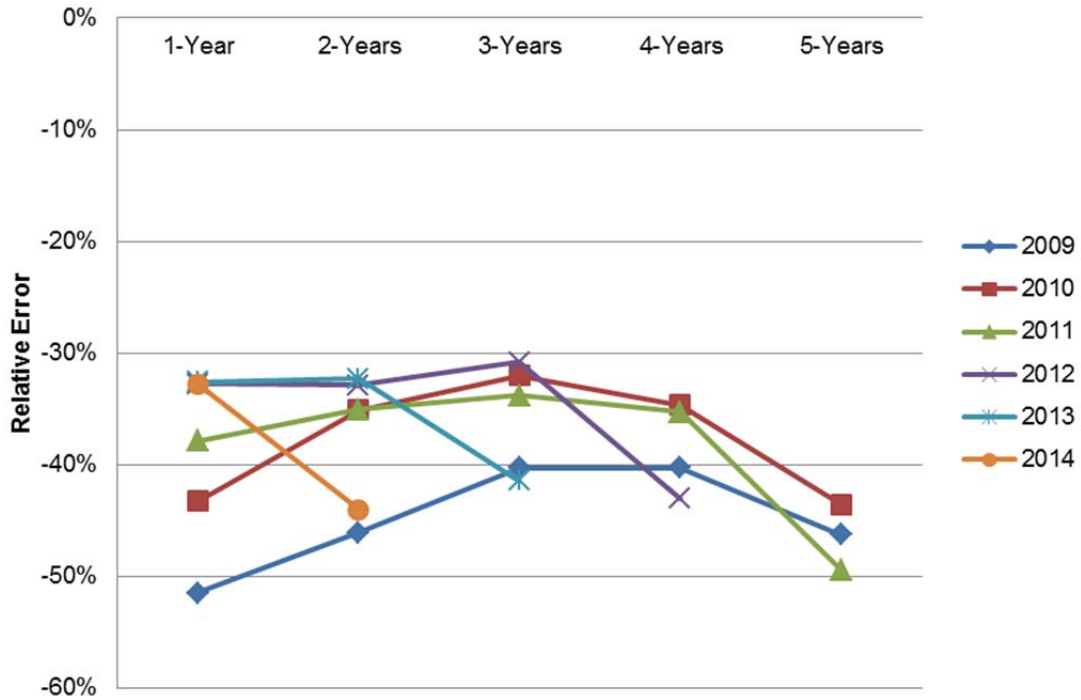
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *Neas.n* and *Neas.e* for the targeted year. τ was the quantity of Marines pulled from TFDW with the separation code *NEAS* for the targeted year.

Figure 31.   NEAS Losses Relative Error
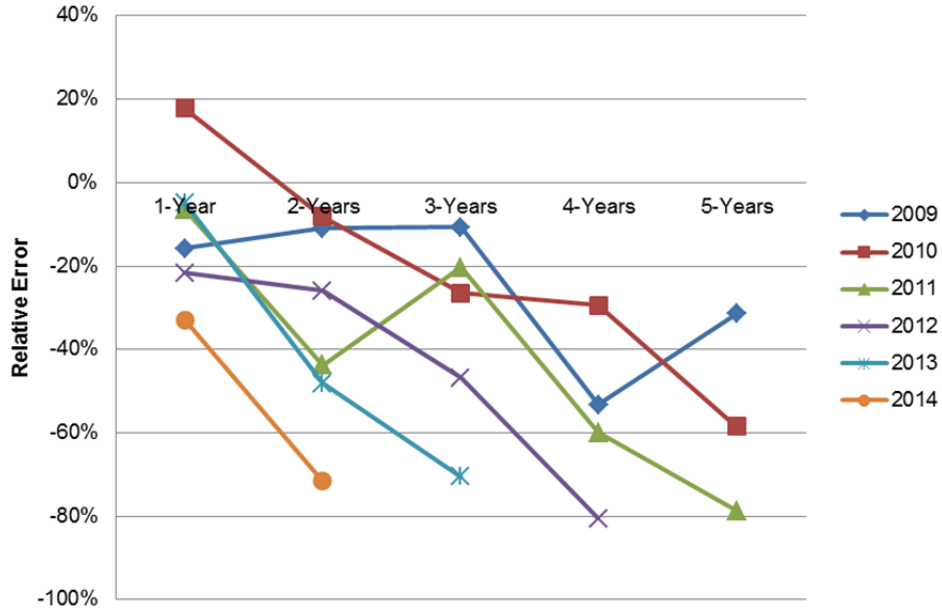
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *Retired.n* and *Retired.e* for the targeted year. τ was the quantity of Marines pulled from TFDW with the separation code *Retired* for the targeted year.

Figure 32.   Retired Losses Relative Error
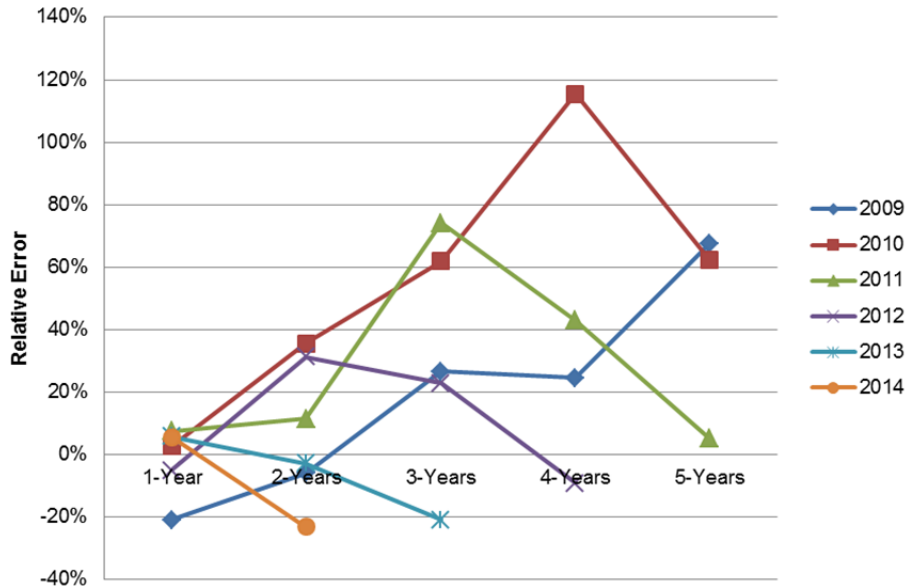
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *Other.n* and *Other.e* for the targeted year. τ was the quantity of Marines pulled from TFDW with the separation code *Other* for the targeted year.

Figure 33.   Other Losses Relative Error
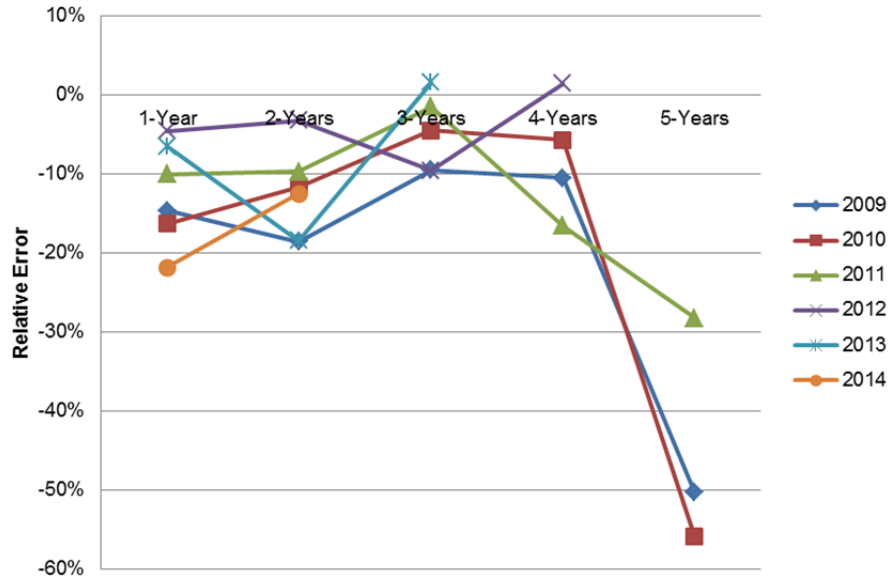
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *Eas.n* and *Eas.e* for the targeted year. τ was the quantity of Marines pulled from TFDW with the separation code *EAS* for the targeted year.

Figure 34.   EAS Losses Relative Error
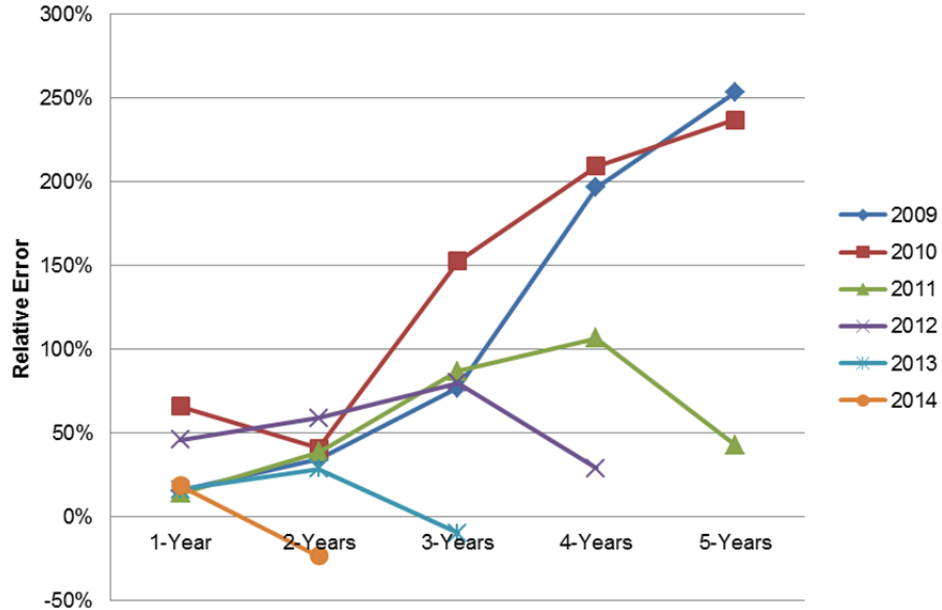
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *Ead.g, Occ.g, Rev.g, Cont.g, Broke.g, Des.g,* and *Other*.g for the targeted year. τ was the quantity of Marines pulled from TFDW with the same gain codes for that year.

Figure 35.   Aggregated Gains Relative Error
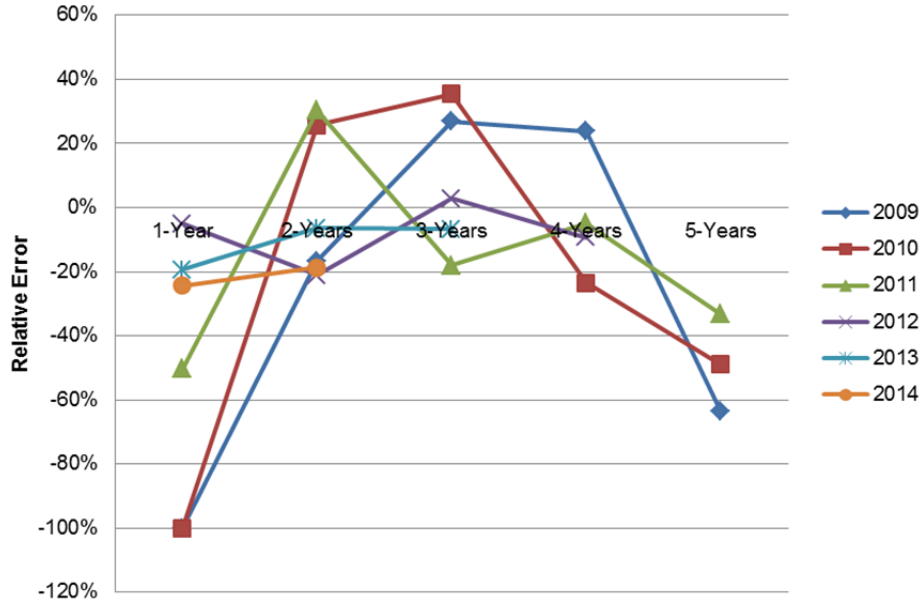
Points were calculated with Equation 6. $\overline{X}$ was the output *NPS.g* for the targeted year. τ was the quantity of Marines pulled from TFDW for total accessions for the targeted year.

Figure 36.   Accession Gains Relative Error
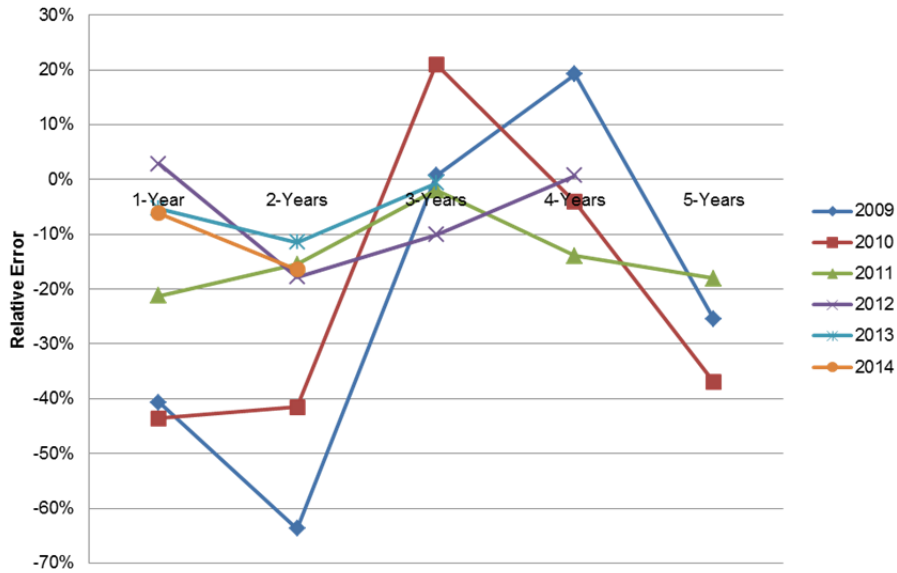
Points were calculated with Equation 6. $\overline{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-2 for targeted year, pulled from TFDW.

Figure 37.   Promotions to E-2 Relative Error
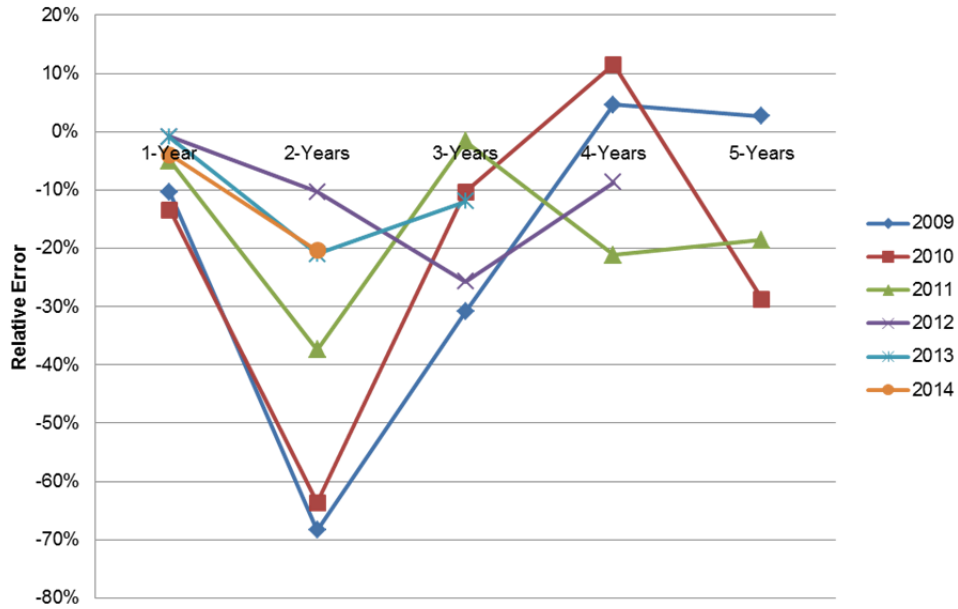
Points were calculated with Equation 6. $\overline{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-3 for targeted year, pulled from TFDW.

Figure 38.   Promotions to E-3 Relative Error
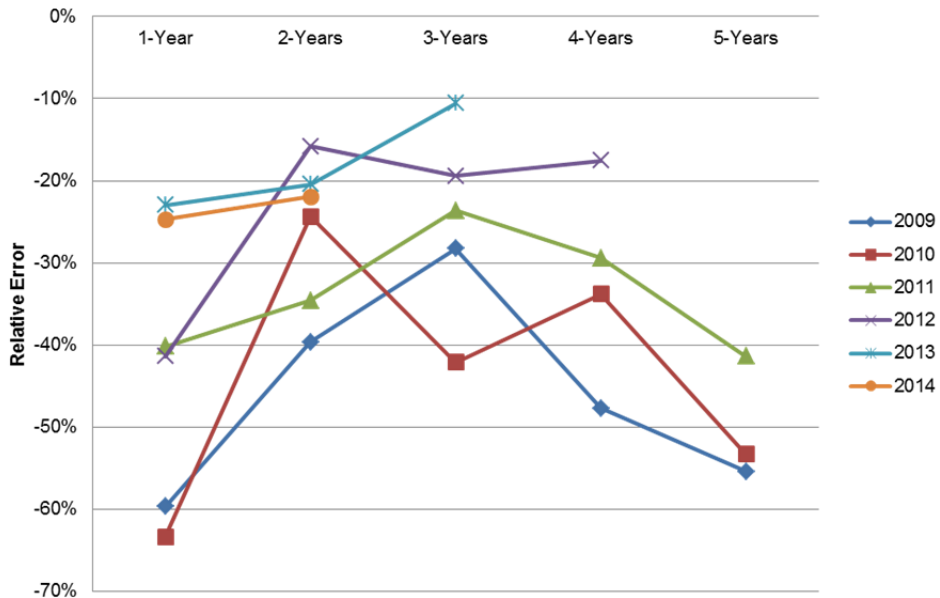
Points were calculated with Equation 6. $\overline{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-4 for targeted year, pulled from TFDW.

Figure 39.   Promotions to E-4 Relative Error
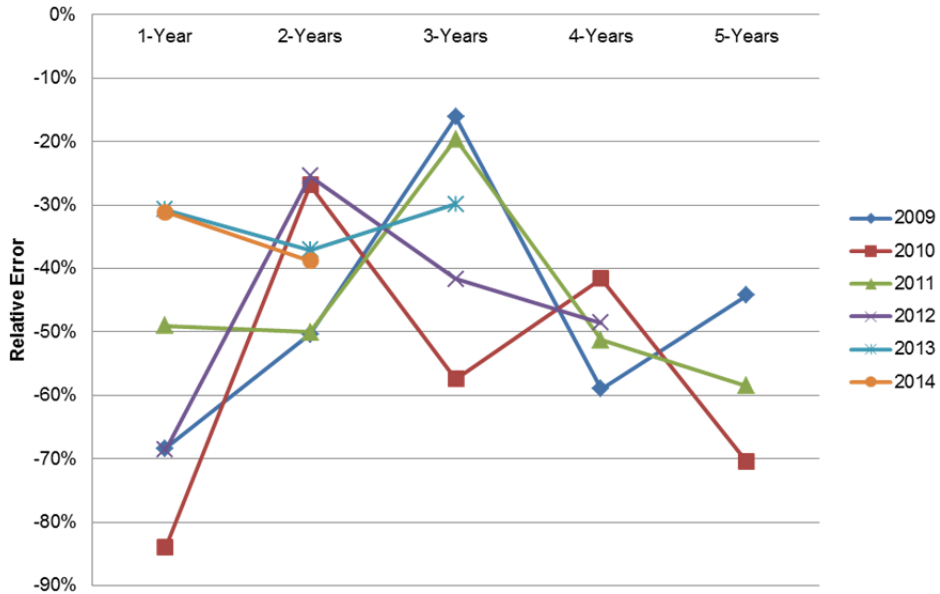
Points were calculated with Equation 6. $\overline{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-5 for targeted year, pulled from TFDW.

Figure 40.   Promotions to E-5 Relative Error
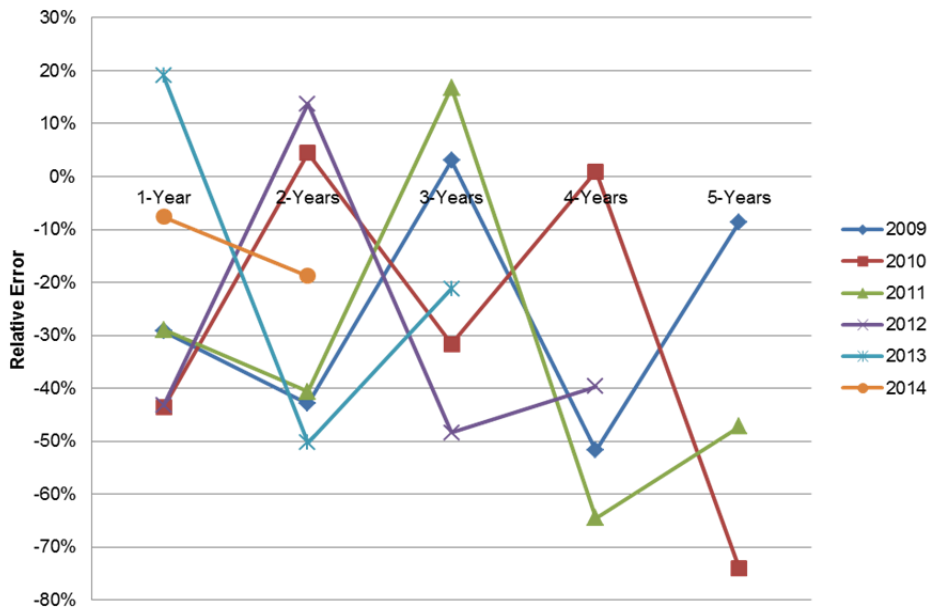
Points were calculated with Equation 6. $\overline{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-6 for targeted year, pulled from TFDW.

Figure 41.   Promotions to E-6 Relative Error
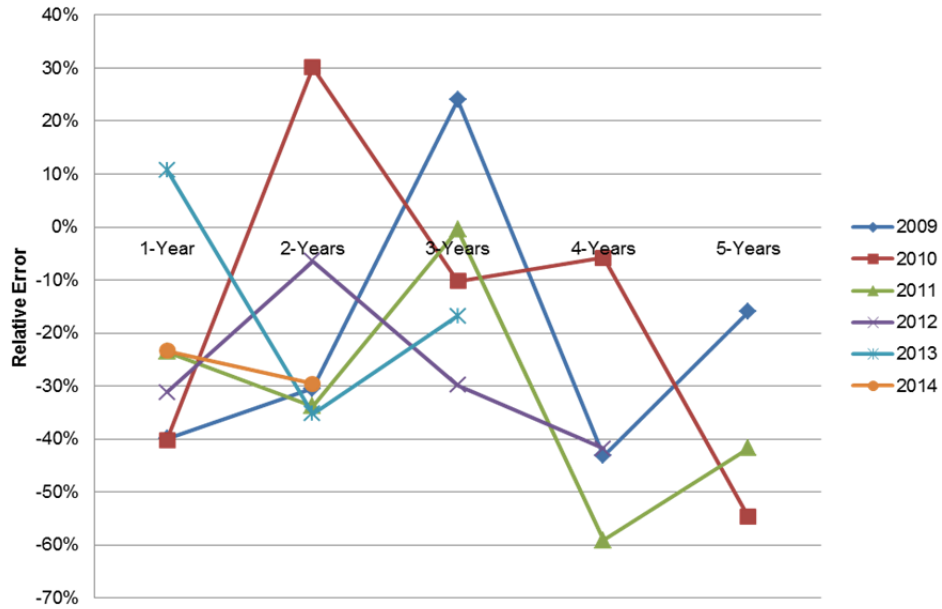
Points were calculated with Equation 6. $\overline{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-7 for targeted year, pulled from TFDW.

Figure 42. Promotions to E-7 Relative Error
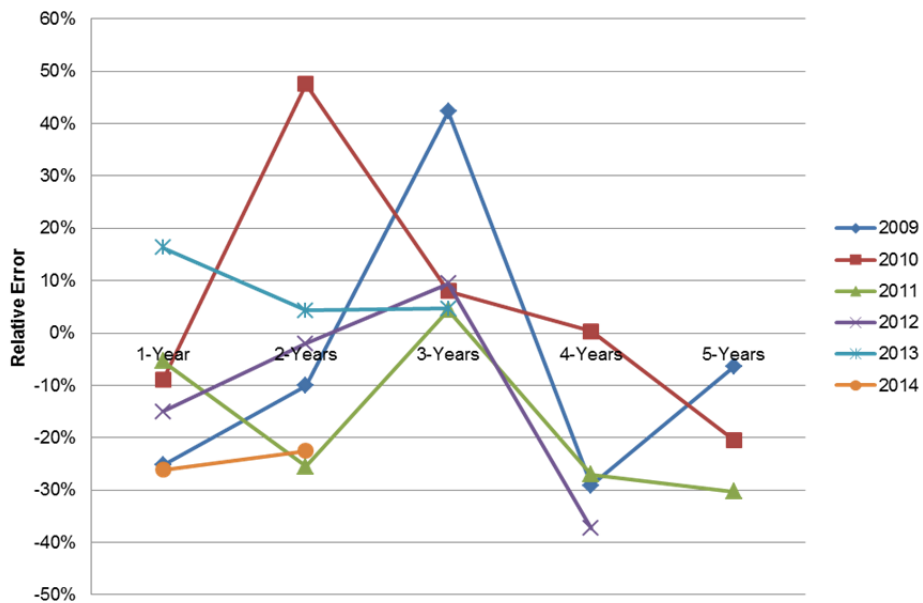
Points were calculated with Equation 6. $\overline{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-8 for targeted year, pulled from TFDW.

Figure 43. Promotions to E-8 Relative Error
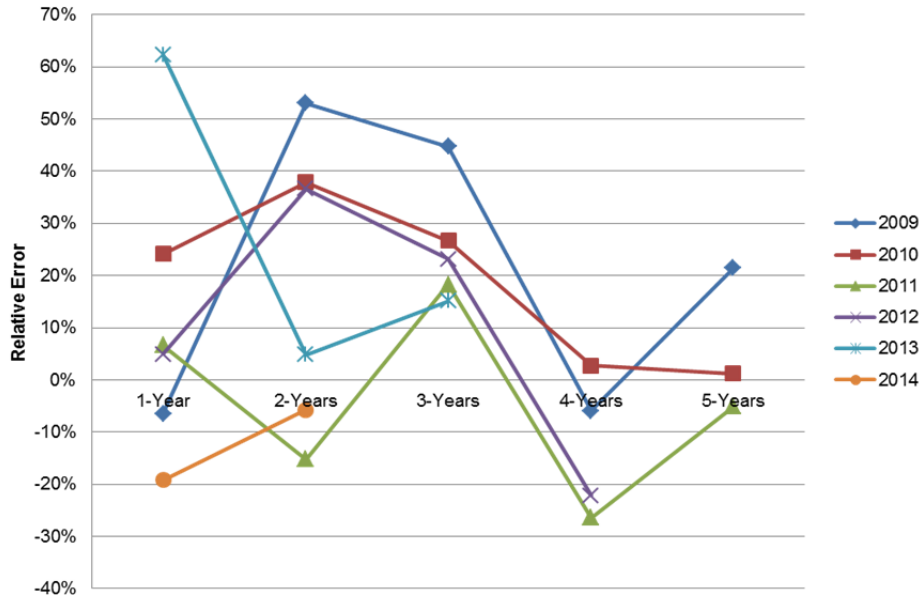
Points were calculated with Equation 6. $\bar{X}$ was the tier II output *PromIn* for the targeted year at the respective grade. τ was the quantity of Marines promoted to E-9 for targeted year, pulled from TFDW.

Figure 44.   Promotions to E-9 Relative Error
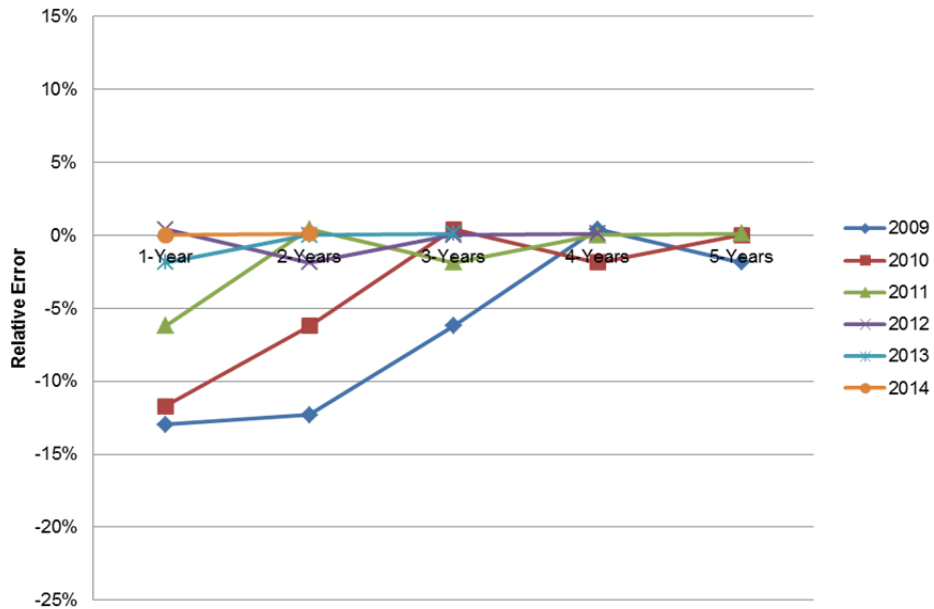
Points were calculated with Equation 6. $\bar{X}$ was output *End* for the targeted year. τ was the total quantity of Marines within TFDW for targeted year.

Figure 45.   End Strength Relative Error
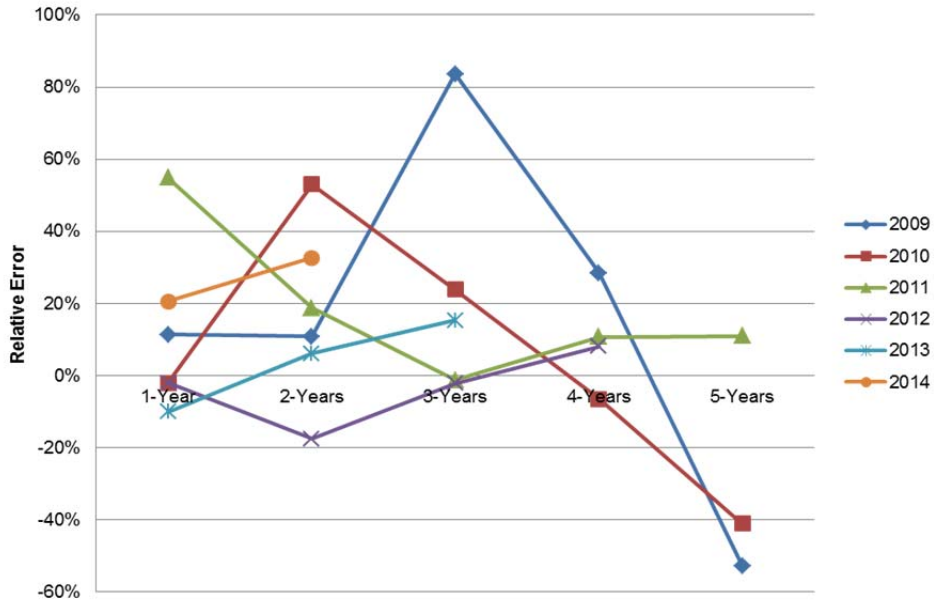
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *A.i, A.naf,* and *A.o.* τ was the quantity of Marines retained within *Zone-A*, pulled from TFDW for the targeted year.

Figure 46.   Retention Zone-A Relative Error
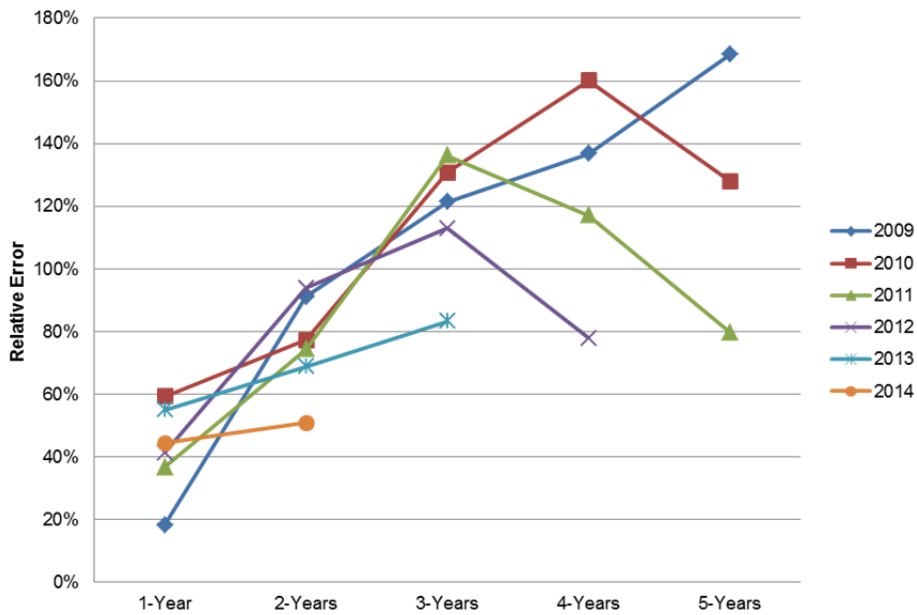
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *B.i, B.naf,* and *B.o.* τ was the quantity of Marines retained within *Zone-B*, pulled from TFDW for the targeted year.

Figure 47.   Retention Zone-B Relative Error
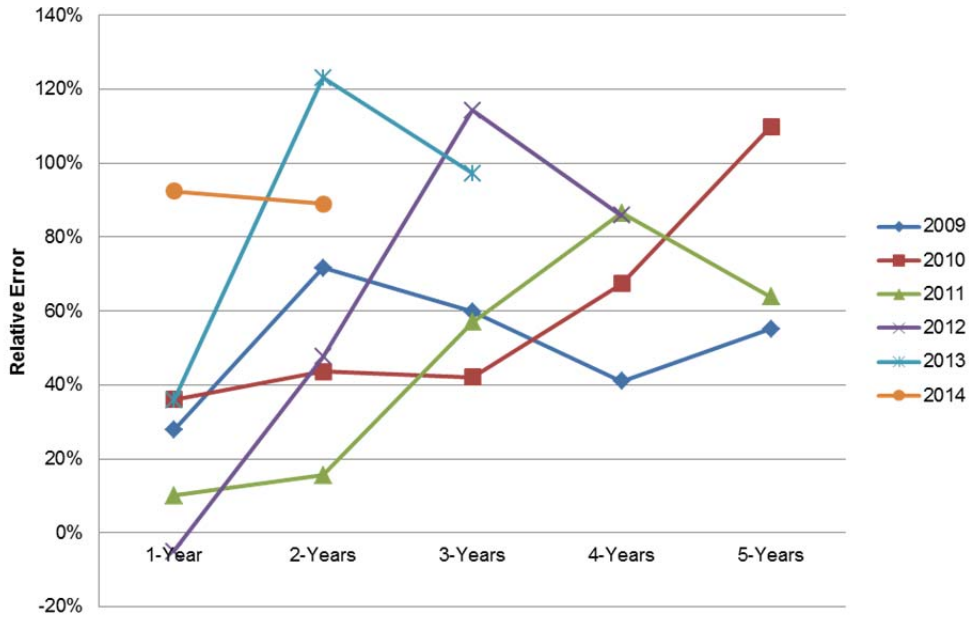
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *C.i,* *C.naf,* and *C.o.* τ was the quantity of Marines retained within *Zone-C*, pulled from TFDW for the targeted year.

Figure 48.   Retention Zone-C Relative Error
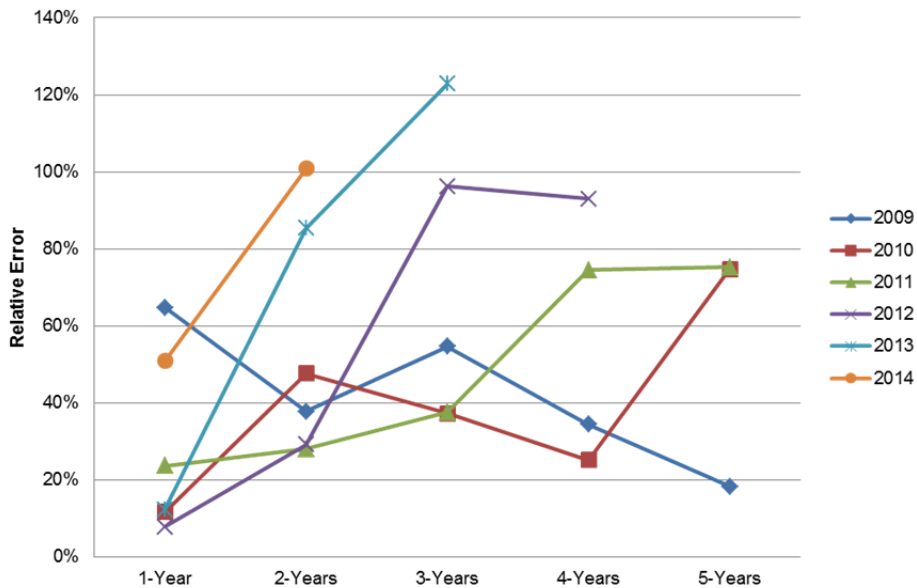
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *D.i,* *D.naf,* and *D.o.* τ was the quantity of Marines retained within *Zone-D*, pulled from TFDW for the targeted year.

Figure 49.   Retention Zone-D Relative Error
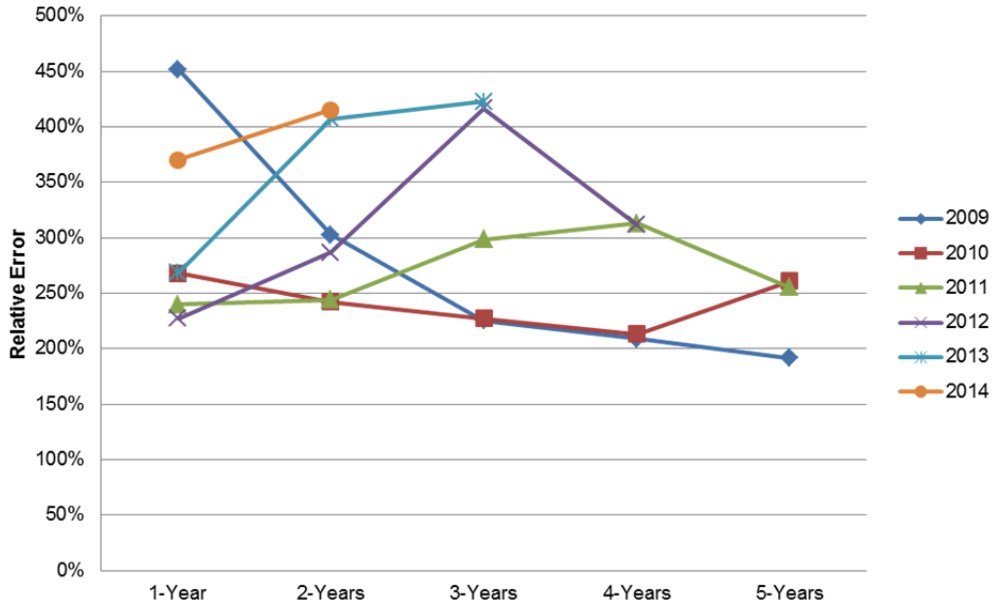
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *E.i, E.naf,* and *E.o.* τ was the quantity of Marines retained within *Zone-E*, pulled from TFDW for the targeted year.

Figure 50.   Retention Zone-E Relative Error
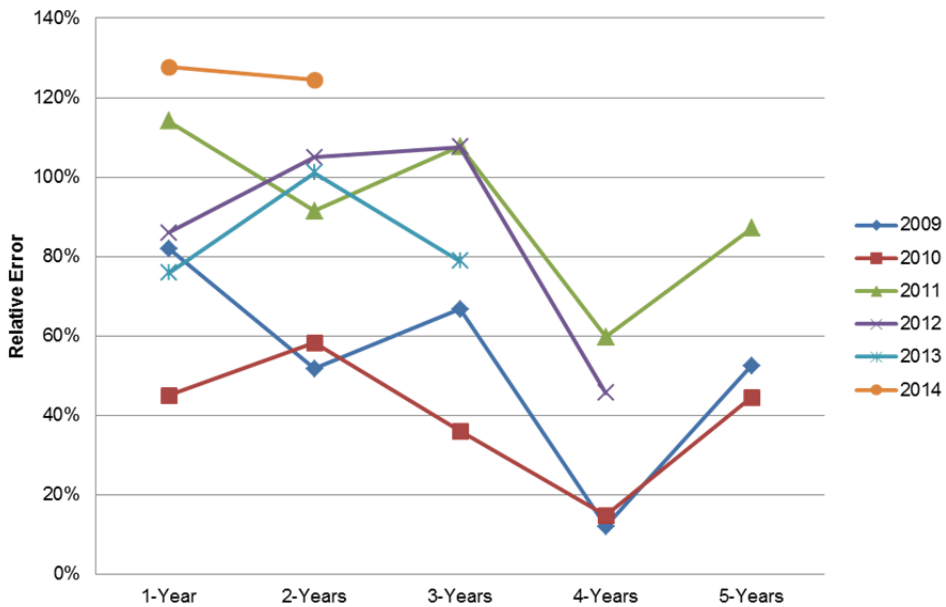
Points were calculated with Equation 6. $\overline{X}$ was the sum of the outputs *SR.i, SR.naf,* and *SR.o.* τ was the quantity of Marines retained within *Zone-SR*, pulled from TFDW for the targeted year.

Figure 51.   Retention Zone-Senior-Enlisted Relative Error

D.   VALIDATION ANALYSIS

On average, the simulation runs that began with 2009 and 2010 typically had the worst relative errors for each category This consistency through the model suggests that an external, uncontrolled factor, affected manpower data and therefore affected the MSM's validation. Losses and Gains showed similar relative error characteristics. Surprisingly, both these graphs produced groupings of minimal error that clustered in the second to forth forecasted year range, with the larger errors occurring immediately in simulation and then toward the end. With regard to promotion, the MSM performed well when forecasting promotions to the Staff Non-Commissioned Officer (SNCO) ranks. Promotions to Non-Commissioned Officer (NCO) ranks were consistently underestimated. Interestingly though, this was reciprocated in the retention zone graphs as most of the graphs consistently overestimated the quantity of Marines that would reenlist. End Strength overwhelmingly returned the lowest relative error out of all the categories evaluated. This once again reinforced that the MSM's most important input is the GAR inventory structure it simulates to.

The most interesting observation was the correlation between reenlistment gains and accessions. All previous investigation identified the MSM to implement a simple supply and demand philosophy; once a billet becomes vacant then the MSM will exhaust all opportunities to move a Marine Agent into the spot by either a lateral move, a promotion, or a lateral move and a promotion simultaneously. What was interesting to discover is that the MSM is biased in choosing Marine Agents to reenlist vice instantiating Marine Agents through the recruit and accessions process. This is seen in the Results Section in that all reenlistment zones constantly overestimated targeted values, while the accessions process continuously underestimated its target values.

VI. CONCLUSION

A. EVALUATION

This thesis had three main objectives to accomplish. The first was to provide a document that explains the architecture and processes of the MSM. The second was to examine how the inputs drive the model, and compare to the HRDP. And lastly, we had the objective to evaluate the accuracy of the model by a validation approach.

The MSM is a large complex program. It totals just over 60 Java classes for its source code, as well as requires eight libraries to function. This program has numerous details that an analysist could spend days, if not weeks, diving into and investigating. With respect to the objectives of this thesis, we reached several important conclusions.

- The MSM is a simple supply and demand process.

While numerous stochastic processes and deterministic algorithms are included within the MSM to forecast manpower metrics, these all abide by the single rule that a billet vacancy must exist for a Marine Agent to move into it. Likewise, if billet vacancies do exist, the MSM will exhaust every inventory option to fill any empty MOS-Grade billets.

- The GAR input is the most important input that drives the MSM and its manpower forecasts.

With the MSM a supply and demand process, the most important input that all algorithms are run against is the GAR structure. The GAR sets targeted billet quantities for each MOS per grade. While the MSM uses stochastic processes and deterministic algorithms to simulate the movement of Marine Agents within the Marine Corps, the MSM will always try to fill any vacant billet seat in order to achieve an inventory that maximizes every available billet seat specified by the GAR. Therefore, the MSM could be viewed more as a tool that evaluates future GAR drafts.

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- The MSM offers many options that allow a user to fine tune particular parameters for a simulation run.

At its foundation, the MSM possesses all the necessary capabilities to run simulations and provide forecasted manpower metrics. Specifically, it uses historical data pulled from its reference inputs to set the likelihood that manpower events occur, and guides the simulation to fully populating the GAR structure. Sitting programmatically on top of that, the MSM provides numerous fields within its "siminputs" Excel input file that allows the user to fine tune simulation parameters. It is recommended to only use these tuning parameters when small deviations to input files or ad hoc case scenarios need to be simulated. Examples of situations range from adjusting the percentages of male and female Marines per allotted end strength to adjusting overall allowable end strength. Outside of ad hoc case scenarios, the primary effort should be given to adjusting the input GAR structure and selecting archival database reference input sequences that closely align with the manpower goals toward which M&RA is looking to forecast.

- The MSM was constructed with a bottom-up methodology that captures key processes within the HRDP.

The power of the model rests in its ability to integrate the numerous processes of HRDP into a single simulation model and simulate down into the details at the Marine MOS-Grade level. Reinforcing this capability is the plethora of data attributes which provide the user with output measurements that can be viewed at different Tier levels depending on the level of detail the user wants to drill into. The Tier I level provides a simple aggregation of the entire Marine Corps for a single forecasted year, Tier II breaks that down further into providing MOS-Grade details for a single forecasted year, and lastly Tier III breaks the data down even further to provide MOS-Grade details by monthly intervals.

- The MSM uses a modular architecture structure.

Each process of the HRDP was constructed as its own Java class, and is only invoked when that HRDP is required to be executed. This greatly increases

the feasibility of editing the MSM because the editor just needs to ensure the parameter(s) being passed to and returned from the invoked Java class remain aligned. All other edits can be made within a process with little dependencies on the remainder of the MSM. Besides easiness in editing, modularity can also facilitate specific policies to be simulated and analyzed. For example, if M&RA wanted to update policies on how promotion boards are run, the Promotions Java class could easily be edited to reflect a drafted policy, which would ultimately produce simulation output metrics that would show HRDP whole effects to a single policy change.

- The MSM is a time-step model with the base time increment set at one fiscal year.

The model simulates the HRDP by employing a waterfall technique for all the processes, where a bulk ingest queuing methodology is utilized. Here, the entire inventory of Marine Agents line up and execute an itemized process, only to move onto the next HRDP process after the last Marine Agent finishes the previous one. Additionally, each Marine Agent only has one chance at executing a certain event within a process, and then that Marine Agent will have to wait a full fiscal year simulation cycle to be afforded another chance.

- MSM employs rudimentary behavior modeling techniques (artificial intelligence).

For Marine Agents navigating their careers within the MOS-Grade state graph network, basic deterministic rules dictate the paths that Marine Agents will navigate. They are simply either allowed to do something or they are not; a binary decision. The only behavior modeling capability that is given to Marine Agents is in the form of statistical probability in a Markov Chain application. For the two types of non-deterministic processes used, a Mersenne Twister random number generator picks the event a Marine Agent will execute, for that respective HRDP process, based on the probabilities of the respective events.

Overall, the MSM is an exceptionally powerful tool that correctly employs the numerous processes of the HRDP. While the level of accuracy of its output

measures varies depending on which output measurement is being examined, overall it provides tangible data points that prior to this model could have only been talked about in theory. For that, it is recommended for continued use and incorporating into plans for future improvements.

B.   RECOMMENDATIONS

While the MSM is a power simulation tool, we identified various areas were continued work and research could be applied.

- Continued Validation

While this thesis examined the MSM's input sensitivity with respect to eight metamodels and validated the MSM against 21 manpower categories, plenty of opportunities exist to dive deeper into the output measures and validate their results. For example the eight metamodels focused primarily at the whole Marine Corps' aggregated level, whereas the validation also drilled down into the Grade metric. This thesis did not continue examining down into the MOS-Grade levels, Tiers II and III of the output measures. Additionally, none of the finance capabilities of the MSM were examined in this thesis.

- MSM Parameter Tuning

The validation results, illustrated in Chapter V, reveal general patterns to MSM's output metrics accuracy with regard to which year in the future it is forecasting for. This implies that parameters could be weighted, and therefore tuned, in order to drive that output metric closer to a zero percentage relative error.

- Intelligent behavior

As previously stated, the Marine Agents follow simple decision rules and the simulated selection boards are likewise simple. There are a wide range of aspects and areas that could be amended with additional behavior characteristics that would render the model a more accurate depiction of real-life Marine Corps manpower decisions. For example, a reenlistment bonus behavior

could be constructed that improves the likelihood of a Marine Agent to reenlist based upon the size of the incentive.

- Add geographical code and/or Unit Identification Code attributes to Marine Agents

Just as the Marine Corps' Table of Organization allocates billets to units, the MSM could add the additional Unit Identification Code (UIC) attribute to each Marine Agent in order to track additional metrics. Specifically, the geographical area could be mapped to these codes, and therefore a Permanent Change of Station Java class could be constructed that forecasts the financial surge associated with Marines moving to new commands in new geographical areas. Likewise, a UIC attribute could be added to each Marine Agent. This attribute could be used to simulate staffing goals for units as well as more accurately map the career progression of a Marine Agent traversing the MOS-Grade state graph network.

- Introduce a Graphic User Interface (GUI)

Numerous steps exist for setting up and running the MSM. From loading all the inputs to setting user defined parameters within the "siminputs" input file, these steps require an intricate level of knowledge about the MSM in order to be done correctly. Converting the user interaction with the MSM into a GUI would better facilitate the process for the user to accurately set up and run the model.

- MSM output data type

The current version of the MSM writes its data outputs to a text-type document. A few modifications to the outputs Java class could transcribe these documents into Excel files, such as comma separated files. Additionally, modifications to the Java class could automatically produce specifically sought after visual graphics.

- Remove MSM's retentions over accessions bias

A negative aspect of the MSM is that it overestimates Marine Agents that choose to reenlist. This has consequences that trickle down through the MOS-Grade state graph network and directly affects the accessions forecasts.

Specifically, because the MSM employs a supply and demand methodology in exhausting all opportunities to retain a Marine Agent, any Marine Agents retained are ultimately occupying billets that make it more difficult for lower grade Marine Agents to promote upwards. This impacts the inventory for each MOS-Grade, which ultimately restricts the quantity of accessions the MSM can instantiate to backfill billet vacancies that have trickled their way down to the entry level MOS-Grades.

APPENDIX A. MSM MODEL INPUTS

Table 5.   Main Sheet Inputs

Parameter	Description
TFDW User Name	User name if pulling from online database
TFDW Password	Password if pulling from online database
ODSE User Name	User name if pulling from online database
ODSE Password	Password if pulling from online database
Scenario Name	Optional scenario name for simulation run
Number of Years	Number of years to forecast
Number of Simulations	Number of repetitions to run the stochastic simulation
Inventory	Sequence number from which to pull inventory data
Initial Forecasted Year	The first year that will be forecasted
Losses	If blank program pulls local file. Enter comma separated list to pull those years from TFDW/ODSE.
Reenlistments	If blank program pulls local file. Enter comma separated list to pull those years from TFDW/ODSE.
Gains	If blank program pulls local file. Enter comma separated list to pull those years from TFDW/ODSE.
Promotions	If blank program pulls local file. Enter comma separated list to pull those years from TFDW/ODSE.
Report Options	Establishes how the program will aggregate its results. - Year - Year and MOS - Year and Grade - Year, MOS, and Grade - Year and Month - Year, Month, and Grade - Year, Month, MOS, and Grade

Table 6.   Career Force Controls

Parameter	Description
Grade	Grade (E1-E9). Each subsequent parameter is broken down and evaluated per grade.
Promotion Targets	Promotion targets for subject grade
Minimum TIS	Controls eligibility for promotion
Maximum TIS	Controls eligibility for promotion and retention
Minimum TIG	Controls eligibility from promotion

Table 6 Continued. Career Force Controls

Parameter	Description
Variable In-Zone Selection Opportunity	Controls zone size, selection rate, and passover rate.
Maximum # of Passovers	Controls whether Marine may continue service
Limit Type if exceed maximum passovers	Indicates type of control to place if passover limit is reached
TIS Limit if exceed maximum passovers	TIS limit adjustment for those who've been passed over

Table 7.   MOS Data

Parameter	Description
PMOS	Digit indicator of primary MOS
Gender	Gender indicator, used on MOS restrictions
Is BMOS	Indicates a basic/school training MOS
Time to Train (Non LM)	Number of days spent in training pipeline
Time to Train (LM)	Number of days spent in training when lat moving to this MOS
Lat Move Only	Indicates if this MOS is a 'Lat Move Only' MOS
Title	Name of MOS
Converting MOSs	List of MOSs that are obsolete predecessors of PMOS
Alias	List of MOSs that PMOS has been known as in the past
Comparable MOSs	List of MOSs that can be used in place of subject MOS
Feeds From	List of MOSs that feed into the subject MOS
Feeds To	List of MOSs that the subject MOS feeds into
Min Grade	Minimum grade for subject MOS
Max Grade	Maximum grade for subject MOS
TOE (4)	4-Year contract
TOE (5)	5-Year contract
TOE (6)	6-Year contract

APPENDIX B. GAR INPUT

The GAR is a user-provided input to the MSM program. Its data is responsible for building the MOS-Grade state graph network of the model, which serves as the manpower structure that the Marine Agents navigate through during the simulation of their career. The below image is a snapshot of this input:

```
TARGET FORCE PLANNING MODEL     ENLISTED GAR BUILD REPORTS

          NN FY16 Enl 175k                              PAGE NO.    4


MOS                      E9    E8    E7    E6    E5    E4    E3   E2/1 TOTAL
0300 ASR                  0     0     0     0     0     0     0     0     0
     TOTAL A-BILLETS       0     0     0     0     0     0     0     0     0
     TOTAL B-BILLETS       0     0     0     0     0     0     0     0     0
     TOTAL A+B BILLETS     0     0     0     0     0     0     0     0     0
     NAR BILLETS           0     0     0     0     0     0     0     0     0
     T2P2                  0     0     0     0     0     0  1557     0  1557
     NAR                   0     0     0     0     0     0  1557     0  1557
     GAR                   0     0     0     0     0     0  1557     0  1557


0311 ASR                  0     0     0     0   872  2317  6336     0  9525
     TOTAL A-BILLETS       0     0     0     0   872  2317  6336     0  9525
     TOTAL B-BILLETS       0     0     0     0   607   540  1466     0  2613
     TOTAL A+B BILLETS     0     0     0     0  1479  2857  7802     0 12138
     NAR BILLETS           0     0     0     0  1479  2857  7802     0 12138
     T2P2                  0     0     0     0    54   359     0     0   413
     NAR                   0     0     0     0  1533  3216  7802     0 12551
     GAR                   0     0     0     0  1533  3216  7802     0 12551


0313 ASR                  8    15    46    73   107   160   345     0   754
     TOTAL A-BILLETS       8    15    46    73   107   160   345     0   754
     TOTAL B-BILLETS       0     0     6    23    33    14     3     0    79
     TOTAL A+B BILLETS     8    15    52    96   140   174   348     0   833
     NAR BILLETS           8    15    52    96   140   174   348     0   833
     T2P2                  0     0     1     3     5    18     0     0    27
     NAR                   8    15    53    99   145   192   348     0   860
     GAR                   8    15    53    99   145   192   348     0   860
```

Figure 52.   Snapshot of GAR Input.

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APPENDIX C. OUTPUT METRICS

Table 8.   MSM Output Metrics

Category	Metric	Definition
Summary of Data Attributes Input into MSM	A-Bil	Pulled from the GAR input, these are primary, direct billets without allocation of overhead, b-billets, training, etc. The "naive" requirement.
	B-Bil	Pulled from the GAR input, these are B-Billets allocated to structure.
	P2T2.gar	Pulled from the GAR input, these are "Overhead" allocated for patients, prisoners, trainees, and transients.
	Gar.u	This is unadjusted "raw" GAR requirement which doesn't account for allocation of those in boot camp or MOS school. Its formula is: **Gar.u = A-Bil + B-Bil + P2T2.gar**
	Train.Boot	Proportional allocation to account for Marines in Boot Camp.
	Train.Mos	Proportional allocation to account for Marine in MOS School
	Gar.a	GAR adjusted for Boot Camp and MOS School allocation. This is the calculation used to build the MOS-Grade state graph network. Its formula is: **Gar.a = Gar.u + Train.Boot + Train.Mos**
	Start	Starting inventory pulled from TFDW data. Always based on FY Start (1 Oct)
	FemStart	Starting female inventory
Loss Category Forecasts Codified with "Non-EAS" Separation Code	Neas.n	Quantity of Marine Agents selected to exit the Marine Corps with a Non-EAS separation code.
	Deaths.n	Quantity of Marine Agents selected to exit the Marine Corps due to death.
	E2O.n	Quantity of Marine Agents selected to receive an enlisted to officer (e2o) commission, and therefore leave the enlisted manpower structure.
	Retired.n	Quantity of Marine Agents selected to exit the Marine Corps due to retiring.
	Other.n	Quantity of Marine Agents selected to exit the Marine Corps due to other means not documented with a specific separation code.
	Eas.n	Quantity of Marine Agents selected to exit the Marine Corps due to the end of their enlisted contract called End of Active Service (EAS).
	Boot.n	Quantity of Marine Agents selected to exit the Marine Corps during bootcamp.

Table 8 Continued. MSM Output Metrics

Category	Metric	Definition
Loss Category Forecasts Codified with "EAS" Separation Code	Neas.e	Quantity of Marine Agents selected to exit the Marine Corps with a Non-EAS separation code.
	Deaths.e	Quantity of Marine Agents selected to exit the Marine Corps due to death.
	E2O.e	Quantity of Marine Agents selected to receive an enlisted to officer (e2o) commission, and therefore leave the enlisted manpower structure.
	Retired.e	Quantity of Marine Agents selected to exit the Marine Corps due to retiring.
	Other.e	Quantity of Marine Agents selected to exit the Marine Corps due to other means not documented with a specific separation code.
	Eas.e	Quantity of Marine Agents selected to exit the Marine Corps due to the end of their enlisted contract called End of Active Service (EAS).
	Boot.e	Quantity of Marine Agents selected to exit the Marine Corps during bootcamp.
Gain Category Forecasts	Ead.g	Quantity of Marine Agents selected that return from their extended active duty (EAD) recruiting tour.
	Occ.g	Quantity of Marine Agents selected that return after having become a deserter.
	Rev.g	Quantity of Marine Agents selected that return to service with a Rever gain code.
	Cont.g	Quantity of Marine Agents selected that return to service with a Cont gain code.
	Brok.g	Quantity of Marine Agents selected that return from medical holds.
	Des.g	Quantity of Marine Agents selected that return after having become a deserter.
	Other.g	Quantity of Marine Agents selected that return to service for other means not captured.
Accession Forecasts	NPS.g	Non-prior service accessions. This field is calculated based on vacancies required to fill requirements or is supplied by the user.
	NPSFem.g	Same as NPS.g, but for females. There is no required female recruiting, so this is an estimate based on data.
General Manpower Metrics	PromIn	Quantity of Marine Agents promoted into category (depending on tier level, could be aggregate FY, by MOS-Grade, by month…ect).
	PromOut	Quantity of Marine Agents promoted out of a categoy (depending on tier level, could be aggregate FY, by MOS-Grade, by month…ect).
	LMIn	Quantity of Marine Agents lateral moved into category (depending on tier level, could be aggregate FY, by MOS-Grade, by month…ect).
	LMOut	Quantity of Marine Agents lateral moved out of a categoy (depending on tier level, could be aggregate FY, by MOS-Grade, by month…ect).
	End	Quantity of Marine Agents in the inventory at the end of the time iteration (could be either by FY or by month)
	FemEnd	Quantity of female Marine Agents in the inventory at the end of the time iteration (could be either by FY or by month)
	P2T2	Quantity of Marine Agents for the aggregated time period (could be either by FY or by month, depends on which output tier viewed).
	BasePay	Estimated Base Pay for inventory based on pay tables
	CompPay	Estimated Composite pay based on by-grade composite planning factors.

Table 8 Continued. MSM Output Metrics

Category	Metric	Definition
MSM Retention Metrics	EligA	Quantity of Marine Agents eligible for retention in zone A.
	EligB	Quantity of Marine Agents eligible for retention in zone B.
	EligC	Quantity of Marine Agents eligible for retention in zone C.
	EligD	Quantity of Marine Agents eligible for retention in zone D.
	EligE	Quantity of Marine Agents eligible for retention in zone E.
	EligSR	Quantity of Marine Agents eligible for retention in zone SR.
	A.i	Quantity of Zone A Marine Agents who reenlisted "In-Year."
	B.i	Quantity of Zone B Marine Agents who reenlisted "In-Year."
	C.i	Quantity of Zone C Marine Agents who reenlisted "In-Year."
	D.i	Quantity of Zone D Marine Agents who reenlisted "In-Year."
	E.i	Quantity of Zone E Marine Agents who reenlisted "In-Year."
	SR.i	Quantity of Zone SR Marine Agents who reenlisted "In-Year."
	A.naf	Marine Agents that reenlisted into zone A that were "Not Accounted For" (see end note).
	B.naf	Marine Agents that reenlisted into zone B that were "Not Accounted For" (see end note).
	C.naf	Marine Agents that reenlisted into zone C that were "Not Accounted For" (see end note).
	D.naf	Marine Agents that reenlisted into zone D that were "Not Accounted For" (see end note).
	E.naf	Marine Agents that reenlisted into zone E that were "Not Accounted For" (see end note).
	SR.naf	Marine Agents that reenlisted into zone SR that were "Not Accounted For" (see end note).
	A.o	Quantity of Zone A Marine Agents who reenlisted "Out-of-Year" (i.e. EAS in 2017 but Marine Agent reenlisted in 2016).
	B.o	Quantity of Zone B Marine Agents who reenlisted "Out-of-Year" (i.e. EAS in 2017 but Marine Agent reenlisted in 2016).
	C.o	Quantity of Zone C Marine Agents who reenlisted "Out-of-Year" (i.e. EAS in 2017 but Marine Agent reenlisted in 2016).
	D.o	Quantity of Zone D Marine Agents who reenlisted "Out-of-Year" (i.e. EAS in 2017 but Marine Agent reenlisted in 2016).
	E.o	Quantity of Zone E Marine Agents who reenlisted "Out-of-Year" (i.e. EAS in 2017 but Marine Agent reenlisted in 2016).
	SR.o	Quantity of Zone SR Marine Agents who reenlisted "Out-of-Year" (i.e. EAS in 2017 but Marine Agent reenlisted in 2016).

Table 8 Continued. MSM Output Metrics

Category	Metric	Definition
Other Manpower Metrics	Passovers	Number of times Marine Agents are passed over for promotion, aggregated.
	PromZoneElig	Number of Marine Agents eligible for promotion and placed in zone, aggregated.
	PromElig	Number of Marine Agents eligible for promotion, irrespective of whether or not they were placed in zone.
	sumTTP	The aggregated sum of Time to Promotion.
	sumTIG	The aggregated sum of Time in Grade.
	sumYOS	The aggregated sum of Years of Service.

The ."naf" category is an artifact of archival bad data. Prior to the construction of the MSM, it was identified by M&RA that there was a leakage within the retention accountability system due to various HRDP processes and how they interfaced together. Specifically, there were Marines who were reenlisting that were not being accounted for by either the "in-year" or "out-of-year" retention categories. To account for this group of Marines who were actually reenlisting but not being properly accounted for, the developer built the "not-accounted-for" retention category within the MSM (R. A. Garrick, personal communication, April 6, 2016).

APPENDIX D. DESIGN ORTHOGONALITY

Table 9.   Design Orthogonality of NOLH DOE

	TIS min	TISma x	TIG Min	Prom Tgt	VIZ min	Viz Std	VIZ max	PassO	Re Thsh	Loss Boot	Loss Retir	Loss NEAS	Loss Death	Loss e2o	Loss Other	Loss EAS	Loss Reup	Gain EAD	Gain Destr	Gain Other	Gain OCC	Gain Cont	Gain Rever	Gain Brkn
TISmin	1	0.024	-0.022	-0.016	-0.012	0.02	-0.028	-0.003	-0.04	-0.002	-0.01	0.003	-0.005	0.006	-0.026	0.007	-0.018	0.03	0.004	0.007	-0.014	0.007	-0.011	-0.029
TISmax	0.024	1	0.088	-3E-04	-0.002	-8E-04	0.023	-0.032	-0.005	-0.004	0.015	-0.002	0.009	0.016	0.023	0.013	0.011	-0.007	-0.004	0.005	0.012	0.003	0.011	0.007
TIGmin	-0.022	0.088	1	-0.028	-0.015	-0.015	-0.045	0.003	-0.015	0.029	0.029	0.002	0.011	8E-04	0.017	-0.007	2E-04	0.024	-0.011	0.045	-0.004	0.01	0.031	0.02
PromTgt	-0.016	-3E-04	-0.028	1	-0.001	-5E-04	-0.006	-0.028	0.006	0.002	0.002	-0.002	-3E-04	-0.002	-0.008	-0.002	-0.003	0.009	-6E-04	4E-04	-0.008	0.003	-0.006	-0.006
VIZmin	-0.012	-0.002	-0.015	-0.001	1	-0.003	-0.005	-0.007	0.004	0.005	0.002	-3E-04	-0.004	-0.002	-0.008	-0.004	-0.005	0.006	-0.002	5E-04	-0.007	0.003	-0.005	-0.005
VIZStd	0.02	-8E-04	-0.015	-5E-04	-0.003	1	-0.003	-0.025	-0.007	0.003	7E-04	-7E-04	-0.003	-8E-04	-0.005	-6E-04	-0.002	0.006	-0.002	-0.004	-0.003	0.003	-0.003	-0.002
VIZmax	-0.028	0.023	-0.045	-0.006	-0.005	-0.003	1	0.006	0.021	0.007	0.004	-5E-04	-0.007	-0.004	-0.007	-0.005	-0.008	0.01	-0.003	0.001	-0.01	0.005	-0.008	-0.008
PassO	-0.003	-0.032	0.003	-0.028	-0.007	-0.025	0.006	1	-0.031	0.005	-0.02	-0.02	-0.01	0.004	0.037	0.009	0.01	-0.002	-0.005	-0.017	-0.009	-0.009	0.011	-0.049
ReThsh	-0.04	-0.005	-0.015	0.006	0.004	-0.007	0.021	-0.031	1	-0.017	0.003	0.005	0.01	-0.007	-0.009	-0.022	0.02	0.01	-0.012	-0.011	0.014	-0.06	0.012	-0.017
L.Boot	-0.002	-0.004	0.029	0.002	0.005	0.003	0.007	0.005	-0.017	1	-0.003	-0.001	0.009	0.006	0.009	0.005	0.006	-0.009	0.001	-0.002	0.009	-0.007	0.01	0.007
L.Retire	-0.01	0.015	0.029	0.002	0.002	7E-04	0.004	-0.02	0.003	-0.003	1	-0.003	0.004	0.002	0.004	0.002	0.002	-0.004	1E-03	-1E-03	0.006	-0.003	0.003	0.004
L.NEAS	0.003	-0.002	0.002	-0.002	-3E-04	-7E-04	-5E-04	-0.02	0.005	-0.001	-0.003	1	0.002	-5E-04	0.004	7E-04	7E-05	1E-04	-1E-04	6E-05	0.002	-4E-04	6E-04	3E-05
L.Death	-0.005	0.009	0.011	-3E-04	-0.004	-0.003	-0.007	-0.01	0.01	0.009	0.004	0.002	1	-0.006	-0.012	-0.006	-0.009	0.009	-7E-05	6E-04	-0.012	0.007	-0.009	-0.008
L.e2o	0.006	0.016	8E-04	-0.002	-0.002	-8E-04	-0.004	0.004	-0.007	0.006	0.002	-5E-04	-0.006	1	-0.004	-0.002	-0.004	0.006	-6E-04	2E-04	-0.003	0.005	-0.005	-0.003
LOther	-0.026	0.023	0.017	-0.008	-0.008	-0.005	-0.007	0.037	-0.009	0.009	0.004	0.004	-0.012	-0.004	1	-0.003	-0.009	0.01	-0.001	0.002	-0.013	0.005	-0.011	-0.007
L.EAS	0.007	0.013	-0.007	-0.002	-0.004	-6E-04	-0.005	0.009	-0.022	0.005	0.002	7E-04	-0.006	-0.002	-0.003	1	-0.007	0.004	-0.001	0.001	-0.004	0.002	-0.003	-0.004
L.Reup	-0.018	0.011	2E-04	-0.003	-0.005	-0.002	-0.008	0.01	0.02	0.006	0.002	7E-05	-0.009	-0.004	-0.009	-0.007	1	0.007	-0.002	0.003	-0.007	0.006	-0.008	-0.004
G.EAD	0.03	-0.007	0.024	0.009	0.006	0.006	0.01	-0.002	0.01	-0.009	-0.004	1E-04	0.009	0.006	0.01	0.004	0.007	1	0.001	9E-04	0.008	-0.005	0.01	0.005
GDestr	0.004	-0.004	-0.011	-6E-04	-0.002	-0.002	-0.003	-0.005	-0.012	0.001	1E-03	-1E-04	-7E-05	-6E-04	-0.001	-0.001	-0.002	0.001	1	-0.002	-3E-04	0.003	-7E-04	-0.002
G.Other	0.007	0.005	0.045	4E-04	5E-04	-0.004	0.001	-0.017	-0.011	-0.002	-1E-03	6E-05	6E-04	2E-04	0.002	0.001	0.003	9E-04	-0.002	1	0.001	-2E-04	0.001	4E-04
G.OCC	-0.014	0.012	-0.004	-0.008	-0.007	-0.003	-0.01	-0.009	0.014	0.009	0.006	0.002	-0.012	-0.003	-0.013	-0.004	-0.007	0.008	-3E-04	0.001	1	0.007	-0.01	-0.007
G.Cont	0.007	0.003	0.01	0.003	0.003	0.003	0.005	-0.009	-0.06	-0.007	-0.003	-4E-04	0.007	0.005	0.005	0.002	0.006	-0.005	0.003	-2E-04	0.007	1	0.005	0.005
G.Rever	-0.011	0.011	0.031	-0.006	-0.005	-0.003	-0.008	0.011	0.012	0.01	0.003	6E-04	-0.009	-0.005	-0.011	-0.003	-0.008	0.01	-7E-04	0.001	-0.01	0.005	1	-0.008
G.Brkn	-0.029	0.007	0.02	-0.006	-0.005	-0.002	-0.008	-0.049	-0.017	0.007	0.004	3E-05	-0.008	-0.003	-0.007	-0.003	-0.004	0.005	-0.002	4E-04	-0.007	0.005	-0.008	1

Within the table, the top three correlations (the three worst orthogonalities) are highlighted in yellow.

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APPENDIX E. NOLH DESIGN

Table 10.   NOLH Design

	TIS min	TISmax PassO	TIG max	Prom Tgt	VIZmin	VizStd	VIZmax	Pass over	Reinlist Thresh	Loss Boot	Loss Retired	Loss NEAS	Loss Death	Loss e2o	Loss Other	Loss EAS	Loss Reup	Gain EAD	Gain Desert	Gain Other	Gain OCC	Gain Cont	Gain Rever	Gain Broken
low level	-2	-4	-1	-2	-0.1	-0.05	-0.05	-2	-2	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
high level	3	4	3	4	0.05	0.05	0.1	2	2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
decimals	0	0	0	1	3	3	3	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
factor name	0	2	-1	-0.6	0.015	-0.028	0.023	2	1	0.713	1.055	1.043	0.704	0.659	0.914	0.621	0.637	0.926	1.073	0.696	0.709	1.004	0.877	1.065
	-1	-1	0	-1.6	0.005	-0.032	-0.039	1	-2	0.963	0.772	0.821	1.1	0.772	0.877	0.625	0.666	0.952	1.09	0.666	0.838	0.83	0.844	0.938
	0	2	2	4	-0.061	-0.004	0.008	1	-1	0.905	0.877	1.065	0.676	0.668	0.961	1.055	0.913	0.627	1.088	0.881	0.895	0.647	0.776	0.709
	-1	-2	2	3.8	-0.035	-0.018	-0.044	1	1	0.768	0.799	0.789	0.957	0.633	1.098	0.903	0.866	0.668	0.959	0.868	1.073	0.786	0.743	0.834
	-1	2	0	3.6	-0.096	-0.011	0.016	1	1	1	0.93	0.887	0.641	1.098	0.819	0.862	0.631	1.01	1.096	1.075	1.018	0.678	0.729	0.655
	-1	-2	0	3.3	-0.065	-0.02	0.005	2	-1	0.62	0.76	0.801	0.998	1.1	0.75	0.864	0.793	0.948	0.916	0.95	0.889	0.674	0.633	0.62
	-1	4	3	-0.5	-0.047	-0.034	0.011	1	-2	1.096	0.954	1.012	0.664	0.971	1.041	0.846	0.918	0.659	0.651	0.76	0.823	1.098	0.705	0.776
	-2	-3	3	-0.4	-0.098	-0.025	-0.026	1	2	0.77	0.651	0.793	0.897	1.036	0.922	0.973	1.073	0.809	0.6	0.778	0.864	1.034	0.766	0.604
	-2	4	-1	-0.6	-0.064	-0.017	-0.032	1	2	1.055	0.938	0.875	0.637	0.731	0.604	0.745	0.686	1.071	0.811	0.879	0.614	1.002	0.618	0.668
	-2	-4	-1	-0.2	-0.091	-0.004	0.01	2	-2	0.69	0.786	0.643	0.907	0.803	0.77	0.723	0.83	0.963	0.801	0.756	0.788	0.936	0.795	0.825
	-2	1	2	2.5	-0.021	0.021	0.081	-2	-1	0.668	0.766	0.69	1.096	0.618	0.827	0.635	0.602	1.03	0.657	0.649	0.782	0.924	0.774	0.684
	0	-3	2	2.9	0.038	0.008	0.077	-2	1	0.887	0.92	1.053	0.606	0.645	0.711	0.684	0.606	1.012	0.637	0.766	0.795	0.995	0.784	0.842
	-1	2	0	3	0.029	0.007	0.084	-2	1	0.799	0.606	0.641	1.069	0.918	1.09	0.934	0.989	0.614	0.795	0.834	0.655	0.979	0.647	0.799
	-1	-2	-1	3.4	-0.003	0.047	0.092	-2	-1	1.045	0.87	1.071	0.67	0.938	0.936	0.844	1.051	0.6	0.901	0.782	0.717	1	0.821	0.786
	-1	3	2	-0.2	-0.017	0.033	0.053	-1	-1	0.774	0.807	0.653	0.965	1.026	0.715	0.731	0.731	0.965	0.895	1.065	1.075	0.649	0.748	0.778
	-1	-3	2	-0.8	-0.002	0.008	0.093	-1	1	0.86	1.002	0.961	0.727	0.944	0.606	0.637	0.825	0.938	1.028	0.911	1.028	0.629	0.639	0.791
	-1	2	0	0.2	0.049	0.019	0.038	-1	2	0.663	0.789	0.784	0.983	0.627	0.957	0.852	1.047	0.741	1.061	0.913	1.014	0.6	0.731	0.764
	-1	-3	-1	-1.5	0.027	0.021	0.052	-1	-1	1.075	1.014	0.901	0.748	0.723	0.862	0.932	0.987	0.733	0.928	0.975	0.998	0.637	0.702	0.621
	-1	4	1	1.1	-0.064	0.021	0.097	-1	-1	1.014	0.752	0.83	0.881	0.735	1.059	0.83	0.809	0.987	1.082	0.864	0.694	1.088	0.897	0.961
	-2	-3	2	3.5	-0.073	0.012	0.033	0	0	0.745	0.905	1.092	0.721	0.707	1.047	0.608	0.784	0.995	0.92	0.799	0.807	0.955	0.93	0.926
	0	0	-1	3.2	-0.074	0.045	0.04	-2	1	1.071	0.797	0.811	1	1.018	0.733	0.93	0.946	0.791	1.047	0.762	0.844	1.096	0.862	1.038
	0	-1	0	1.9	-0.084	0.013	0.043	-1	-2	0.696	1.084	0.893	0.61	0.926	0.791	0.916	1.075	0.661	1.041	0.87	0.696	0.901	0.989	0.985
	0	3	1	0.7	-0.055	0.001	0.05	-1	-2	1.012	0.631	0.836	1.086	0.979	1.065	0.829	0.694	1.077	0.641	0.875	0.969	0.729	1.051	1.077
	-1	-1	3	0.1	-0.071	0.04	0.027	-2	0	0.748	0.844	0.965	0.758	1.086	0.92	0.772	0.813	0.928	0.678	1.079	0.891	0.606	0.899	1.043
	-2	0	0	-2	-0.046	0.009	0.034	-1	1	1.028	0.873	0.666	1.084	0.752	0.696	1.028	0.92	0.653	0.682	0.979	0.901	0.856	0.809	0.954
	0	-3	0	-1.1	-0.087	0.005	0.078	-2	-1	0.782	0.916	0.873	0.715	0.87	0.729	0.834	0.936	0.743	0.803	0.971	1.069	0.711	0.944	1.075
	0	1	1	2.3	0.006	-0.002	0.049	-1	-2	0.827	1.059	0.768	1.034	0.815	0.621	0.95	0.651	1.016	0.729	0.973	0.758	1.036	1.03	0.645

Table 10 Continued. NOLH Design

0	0	3	1.7	-0.013	-0.042	0.051	-1	0	0.989	0.809	0.92	0.75	0.612	0.83	0.987	0.647	1.059	0.762	1.084	0.776	1.038	0.871	0.639
-2	0	1	3.7	-0.014	-0.036	0.068	-1	0	0.661	0.895	0.62	0.993	0.932	0.926	0.663	0.873	0.649	0.807	0.893	0.715	1.018	1.006	0.803
0	-3	1	1.8	0.045	-0.015	0.088	-1	-1	0.897	0.657	1.002	0.682	0.899	0.998	0.707	0.854	0.704	0.754	0.873	0.637	1.084	0.911	0.717
0	4	2	1	0.025	-0.005	0.095	-2	-1	0.823	0.909	0.694	1.038	0.832	0.807	1.004	0.729	1.049	1.069	0.752	1.071	0.735	0.975	0.817
-2	-1	1	-1.4	-0.013	-0.015	0.074	-1	1	1.008	0.838	1.084	0.602	0.879	0.707	1.012	0.704	0.993	0.903	0.741	0.993	0.676	1.018	0.68
0	2	-1	0.5	0.004	-0.049	0.059	-1	0	0.754	1.071	0.748	1.02	0.678	0.871	0.786	1.002	0.68	0.844	0.651	0.932	0.657	0.95	0.618
-1	-1	1	0.7	0.007	-0.035	0.048	-1	-2	0.967	0.62	0.942	0.705	0.807	1.006	0.799	1.018	0.612	1.03	0.829	0.975	0.766	0.979	0.643
-1	2	2	2.2	-0.057	-0.026	0.099	0	-1	0.914	0.95	0.649	0.92	0.629	0.959	1.077	0.856	0.979	0.86	1.055	0.649	0.94	0.643	0.932
0	-2	1	1.5	-0.043	-0.032	0.083	-1	1	0.76	0.68	1.086	0.823	0.836	1.069	0.938	0.633	0.842	0.911	0.93	0.663	0.895	0.604	0.934
0	3	0	1.4	-0.092	-0.033	0.071	0	1	0.909	1.039	0.803	0.934	0.955	0.776	0.764	1.08	0.764	0.983	1.094	0.83	0.983	0.791	0.973
-1	-1	0	3.8	-0.044	-0.039	0.031	-1	-1	0.676	0.666	0.981	0.795	0.975	0.735	0.719	1.022	0.788	0.862	0.957	0.735	0.952	0.834	1.09
-2	1	2	-1	-0.026	-0.02	0.066	-1	0	1.051	1.004	0.815	0.959	0.961	0.86	1.03	0.664	0.901	0.77	0.631	0.887	0.813	0.739	1.047
0	-4	1	0.5	-0.085	-0.03	0.036	-1	1	0.856	0.731	0.963	0.659	0.998	0.854	0.885	0.61	0.905	0.663	0.678	1.043	0.768	0.696	1.012
0	2	1	-0.1	-0.038	-0.014	0.087	-1	2	0.864	1.065	0.633	0.87	0.84	0.682	0.659	0.905	0.746	0.735	0.784	1.055	0.788	0.606	0.864
-1	-1	-1	-0.3	-0.032	-0.041	0.09	0	0	0.797	0.821	1.038	0.772	0.719	0.799	0.704	0.973	0.643	0.766	0.801	1.096	0.789	0.811	0.928
-2	3	2	4	-0.001	0.038	-0.006	-2	0	0.807	0.647	0.909	0.875	0.737	0.637	0.666	1.041	0.95	0.733	0.776	0.971	0.957	0.664	0.891
-2	-3	1	3.3	0.001	0.034	0.013	0	1	0.938	1.026	0.774	0.668	0.69	0.815	0.614	0.883	0.971	0.75	0.817	0.922	0.905	0.817	0.893
0	2	-1	2.9	0.018	0.039	0.014	-1	2	0.651	0.649	1.098	1.01	0.985	0.911	1.051	0.758	0.768	0.684	0.668	0.866	0.985	0.836	1
-1	-1	-1	1.3	0.038	0.045	-0.045	-1	-2	1.006	1.1	0.844	0.739	1.075	0.975	1.018	0.762	0.657	0.68	0.709	0.934	1.057	0.745	0.854
0	2	3	-0.6	0.045	0.019	-0.025	-1	-1	0.682	0.637	0.922	1.053	0.983	0.731	0.741	0.909	1.008	1.01	1.002	0.618	0.686	0.793	0.916
-1	0	3	0.6	0.024	0.045	0.013	-2	2	1.088	0.952	0.723	0.719	0.995	0.788	0.805	0.981	0.887	0.975	1.09	0.791	0.772	0.848	1.051
-1	4	0	-1.5	0.009	0.009	-0.004	0	0	0.743	0.832	0.969	0.991	0.795	0.977	1.061	0.803	0.663	0.918	1.063	0.797	0.801	0.764	0.852
-2	-3	1	-1.6	-0.002	0.018	-0.007	-1	-1	0.948	0.955	0.766	0.848	0.686	1.075	0.92	0.709	0.745	0.995	0.954	0.733	0.672	0.602	0.989
0	2	3	2	-0.099	0.048	-0.007	-1	-1	1.067	0.782	0.93	0.879	0.606	0.875	0.825	0.961	0.924	1.067	0.657	0.897	1.006	0.901	0.805
-1	-1	2	2.1	-0.083	0.005	0.007	0	2	0.61	1.057	0.75	0.688	0.793	1.073	0.819	1.059	0.83	1.051	0.813	0.858	0.866	0.903	0.743
-1	4	0	2.7	-0.071	0.01	-0.042	0	1	0.885	0.813	0.903	0.932	0.903	0.616	1	0.823	0.823	0.854	0.907	1.059	0.977	1.088	0.789
-2	-3	0	3.5	-0.031	0.012	0.006	-1	-1	0.727	0.881	0.637	0.856	0.936	0.672	1.09	0.715	0.686	1.071	0.7	0.825	0.981	0.928	0.692
-2	2	2	-1.8	-0.066	0.016	0.024	-1	0	0.875	0.858	1.061	0.987	0.909	1.043	0.612	0.901	0.94	0.768	0.909	0.817	0.752	1.026	0.606
-1	-3	2	-0.9	-0.036	0.001	-0.035	-1	1	0.704	0.983	0.854	0.694	1.002	1.032	0.827	0.862	0.868	0.696	0.838	0.61	0.842	1.092	0.827
0	1	0	-0.4	-0.087	0.006	0.012	0	2	1.047	0.7	0.866	0.955	0.641	0.801	0.86	0.688	0.715	0.643	0.989	0.848	0.797	0.991	0.745
0	-1	-1	0.1	-0.09	0.036	0.018	-1	-1	0.621	0.932	0.819	0.842	0.639	0.719	0.963	0.848	0.666	0.645	1.092	0.704	0.653	1.016	0.75
-1	1	2	3.9	0.031	-0.016	0.021	-1	0	0.715	0.913	1.055	0.963	0.811	0.614	1.071	0.889	0.942	0.709	0.895	1.012	1.065	1.079	1.069

Table 10 Continued. NOLH Design

0	-3	1	1.3	0.027	-0.018	-0.038	-1	0	1.061	0.801	0.832	0.791	0.758	0.661	0.922	1.026	1.096	0.827	0.942	1.098	0.909	1.049	0.887
0	1	1	1.6	0.034	-0.029	-0.029	-2	1	0.659	1.092	0.924	0.977	0.883	0.991	0.788	0.608	0.756	0.602	0.998	0.928	1.012	0.854	0.948
0	0	0	1.7	0.042	-0.042	0.003	-1	-1	1.082	0.741	0.651	0.621	1.051	1.08	0.774	0.768	0.846	0.834	1.082	0.92	1.092	0.985	0.94
0	1	3	0	0.003	-0.046	0.017	-2	-1	0.641	1.028	0.914	1.014	1.08	0.705	0.893	0.995	1.079	0.973	0.6	0.77	0.725	0.873	1.041
0	-1	1	0.9	0.043	-0.032	0.002	-1	2	0.965	0.633	0.823	0.633	0.809	0.803	0.944	1.028	0.899	1.084	0.735	0.7	0.627	1.055	1.026
0	4	1	0.6	-0.012	-0.023	-0.049	0	0	0.78	0.975	1.024	1.065	0.854	1.036	0.668	0.774	0.674	0.926	0.764	0.643	0.704	1.028	0.979
-2	0	1	-1.1	0.002	-0.016	-0.027	-2	0	0.895	0.817	0.604	0.838	0.711	0.946	0.616	0.789	0.698	1.075	0.704	0.86	0.782	1.059	0.996
0	1	2	3.3	-0.097	-0.05	-0.014	0	-2	0.916	1.022	0.971	1.039	0.68	0.852	0.94	1.088	0.934	0.957	1.039	1.088	0.926	0.782	0.69
0	-1	3	3.1	-0.033	-0.039	-0.023	-2	0	0.666	0.602	0.709	0.752	0.616	0.942	1.022	0.899	0.897	0.891	1.008	0.959	1.039	0.719	0.612
-2	2	1	3.3	-0.04	-0.031	-0.024	0	0	0.942	0.86	1.032	0.903	1.053	0.762	0.711	0.69	0.616	0.815	0.932	1.036	0.991	0.723	0.748
0	-4	0	3.7	-0.043	-0.004	-0.034	-1	0	0.834	0.692	0.67	0.817	1.038	0.655	0.618	0.67	0.784	0.989	0.946	0.961	0.852	0.616	0.829
-2	3	3	-0.1	-0.05	-0.027	-0.005	0	-2	0.871	0.871	1	0.989	0.954	1	1.053	1.082	0.922	0.713	0.795	0.666	0.815	0.614	0.754
-1	-4	2	-1.7	-0.027	-0.007	-0.021	-1	2	0.766	0.737	0.756	0.788	0.873	0.858	1.047	0.885	1.08	0.823	0.614	0.698	0.825	0.727	0.641
-1	3	-1	0.5	-0.034	-0.041	0.004	-2	2	1.043	1.096	1.041	0.893	0.635	0.805	0.795	0.707	0.696	0.756	0.78	0.711	0.623	0.678	0.602
-1	-3	-1	-0.1	-0.078	-0.043	-0.037	0	-2	0.821	0.707	0.743	0.643	0.788	0.746	0.725	0.68	0.848	0.692	0.602	0.752	0.731	0.762	0.877
1	0	1	1	-0.025	0	0.025	0	0	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
1	-3	1	0.3	-0.044	-0.04	-0.05	-2	1	0.981	0.907	1.069	1.008	0.93	0.903	0.877	1.071	1.082	1.014	0.961	0.979	0.954	0.913	1.004
2	1	0	-1.7	-0.058	-0.003	-0.046	-1	0	0.788	0.729	0.6	0.657	0.844	1.088	1.069	1.032	1.098	0.924	0.811	0.981	0.893	0.84	0.975
2	-1	3	0.6	-0.094	-0.031	-0.041	-2	-1	0.998	0.977	1.036	1.028	0.631	0.684	0.817	0.635	0.678	0.979	1.059	1.024	1.082	0.946	1.092
1	3	1	0.2	-0.06	-0.025	-0.032	-2	1	0.631	0.709	0.618	0.623	0.778	0.809	0.705	0.6	0.711	1.092	1.03	0.995	0.877	0.983	0.903
1	0	1	1.6	-0.089	-0.029	-0.013	-1	2	1.057	1.073	0.94	1.061	0.848	1.02	1.026	1.043	0.961	0.635	0.772	0.678	0.67	0.954	0.93
1	1	-1	3	-0.079	-0.041	-0.01	-2	-1	0.68	0.719	0.68	0.746	0.643	0.887	0.909	0.879	0.914	0.655	0.664	0.647	0.61	0.815	1.084
3	-1	1	3.3	-0.027	-0.002	-0.015	0	-1	1.098	0.965	0.946	0.94	1.028	0.645	0.643	0.77	0.61	0.702	0.856	0.62	0.692	0.948	0.899
1	4	2	1.6	-0.089	-0.024	-0.005	-1	0	0.868	0.834	0.696	0.774	0.887	0.647	0.735	0.684	0.793	0.76	0.676	0.621	0.639	0.987	0.965
3	0	-1	0.2	-0.008	-0.029	-0.011	-2	1	0.627	0.985	0.871	0.885	1.008	0.772	0.897	0.952	0.93	0.791	1.006	1.065	0.987	0.666	0.651
1	3	0	-0.3	0.044	-0.011	0.015	0	-2	0.899	0.758	0.721	0.625	1.034	0.821	0.879	1.045	0.973	0.688	0.852	0.963	0.891	0.842	0.713
2	-3	1	-1.8	-0.016	0	-0.046	0	-2	0.778	0.995	0.995	0.899	0.776	1.049	0.715	0.84	0.836	0.664	0.885	1.094	0.838	0.61	0.731
3	3	3	-0.4	-0.005	-0.017	-0.015	0	0	0.881	0.854	0.61	0.782	0.741	0.883	0.801	0.7	0.682	0.793	0.969	0.944	0.959	0.707	0.729
2	-4	0	3.6	-0.011	-0.03	0.003	-1	1	0.717	0.996	1.079	0.864	0.694	0.766	0.971	1.061	0.998	0.881	0.748	0.68	0.77	0.76	0.661
3	2	0	3.2	0.026	-0.03	-0.048	0	-1	0.924	0.711	0.764	0.77	0.799	0.666	0.889	0.928	0.946	0.879	0.842	0.616	0.793	0.668	0.627
2	-1	3	1.1	0.032	-0.003	-0.014	0	-1	0.817	0.967	1.077	1.026	1.045	0.948	0.68	0.621	0.829	1.039	0.68	0.829	0.817	0.875	0.647
1	2	2	3.6	-0.01	-0.022	-0.041	-1	2	1.094	0.836	0.713	0.811	1.012	0.916	0.746	0.735	0.821	0.864	0.707	0.774	0.645	0.688	0.6

Table 10 Continued. NOLH Design

2	0	0	-0.7	-0.085	0.013	0.004	-1	1	0.846	0.774	1.039	0.936	0.934	0.932	0.686	1.024	1.045	0.942	0.672	1.039	0.897	0.78	0.821
1	2	0	0.3	-0.03	0.022	-0.028	-1	-1	0.647	0.979	0.795	0.786	0.862	1.014	0.657	1.008	1.024	0.858	0.803	0.95	0.944	0.62	0.944
2	-2	1	1	-0.072	0.046	-0.031	-1	-1	0.979	0.739	1.022	1.051	0.754	0.836	0.907	0.717	0.731	1.094	0.627	1.049	1.01	0.631	0.993
2	2	2	0	-0.062	0.023	-0.017	-2	0	0.698	1.09	0.672	0.696	0.713	0.676	0.957	0.745	0.817	1.006	0.62	1.047	1.086	0.768	1.036
1	0	0	2.8	-0.069	0.043	-0.048	-2	1	1.086	0.702	1.045	1.016	0.637	0.952	0.641	1.055	0.895	0.707	1.026	0.754	0.633	0.786	0.918
1	1	1	2.8	-0.086	0.036	-0.03	-1	-1	0.729	1.079	0.625	0.608	0.858	0.963	0.891	0.979	0.977	0.737	1.061	0.608	0.727	0.807	0.913
1	-2	1	1.2	-0.028	0.002	-0.017	-1	-1	0.991	0.653	1.014	0.922	0.952	0.608	1.049	0.661	0.672	0.871	0.963	0.692	0.737	0.637	0.959
2	1	2	2.3	-0.061	0.043	-0.022	-1	0	0.858	0.848	0.733	0.729	0.973	0.76	1.1	0.614	0.631	0.698	0.926	0.762	0.778	0.832	0.87
2	0	0	-1.4	0.018	0.011	0.02	-2	2	0.789	0.684	0.954	1.073	0.895	0.717	0.717	0.94	0.866	0.7	0.846	0.885	1.041	1.024	0.614
1	2	-1	0.8	-0.009	0.046	-0.003	-2	-1	0.993	0.973	0.858	0.62	0.95	0.844	0.842	0.903	1.036	0.883	0.663	0.868	1.08	0.83	0.723
3	-2	1	-0.9	-0.024	0.006	0.009	-1	-1	0.764	0.825	0.955	0.871	0.823	0.889	1.036	0.723	0.639	0.746	0.623	0.957	0.873	1.01	0.672
2	3	2	-0.5	0	0.013	-0.004	0	0	0.838	0.889	0.817	0.698	0.61	0.979	0.948	0.819	0.645	0.704	0.809	1.026	1.016	1.075	0.633
2	-3	-1	2.8	0.02	0.009	-0.025	-1	0	0.725	0.713	0.985	0.911	0.676	0.698	0.832	0.836	1.063	0.969	0.877	0.746	0.762	0.967	0.719
2	2	1	3.4	0.02	0.034	-0.013	0	-2	1.022	0.885	0.702	0.731	0.78	0.907	0.655	0.934	1.075	0.868	0.84	0.784	0.733	1.077	0.694
1	-3	2	1.1	-0.021	0.038	-0.001	-2	-1	0.756	0.803	0.895	1.071	1.039	1.008	1.024	0.725	0.782	0.922	0.987	0.76	0.641	0.996	0.682
2	0	2	2.5	0.008	0.01	0.019	-2	1	0.889	1.03	0.782	0.651	0.991	1.067	0.887	0.643	0.7	1.032	0.903	0.819	0.631	0.942	0.78
1	-1	0	0.8	-0.046	-0.05	0.085	-1	1	1.03	1.086	0.809	0.887	1.03	1.01	1.006	0.75	1.092	1.024	0.995	0.745	0.998	1.043	0.666
1	0	0	-0.1	-0.078	-0.047	0.03	0	-2	0.793	0.618	1.018	0.725	0.911	0.987	1.073	0.623	0.885	1.077	0.985	0.854	0.881	0.963	0.856
2	-3	2	0.4	-0.081	-0.044	0.072	0	0	0.995	1.012	0.692	1.055	0.825	0.678	0.604	0.922	0.827	0.977	0.967	0.684	0.916	1.071	0.676
2	2	1	-0.2	-0.067	-0.038	0.062	-2	0	0.674	0.625	0.993	0.805	0.829	0.727	0.606	0.963	0.717	1.079	1.067	0.748	0.946	0.887	0.67
1	-1	1	3	-0.098	-0.025	0.069	-1	0	1.077	0.946	0.627	0.873	0.866	1.071	1.002	0.741	0.981	0.739	0.653	1.032	0.668	1.008	0.758
1	2	0	2.5	-0.08	-0.023	0.086	0	0	0.616	0.676	0.983	0.678	0.819	1.026	0.979	0.743	0.881	0.719	0.643	1.03	0.75	1.065	0.862
1	0	1	2	-0.067	-0.027	0.028	-1	-1	1.036	0.944	0.704	0.938	1.004	0.67	0.758	1.084	0.838	0.62	0.612	0.899	0.864	0.895	0.811
1	1	2	1.2	-0.072	-0.02	0.061	-1	0	0.723	0.668	0.852	0.733	1.043	0.618	0.709	0.944	0.647	0.764	0.655	1.077	0.707	1	0.702
2	-2	-1	0.2	-0.02	-0.024	0.068	-1	1	0.75	0.924	0.788	0.924	1.047	0.782	0.918	0.746	0.903	0.852	1.096	0.723	0.84	0.698	0.881
2	3	0	-1.1	0.003	-0.007	0.041	0	-2	0.852	0.778	0.989	0.756	1.016	0.745	1.08	0.829	1.094	0.825	1.016	0.821	0.879	0.659	0.86
2	-4	2	-1.2	-0.009	-0.048	0.026	-2	-2	0.772	1.006	0.752	0.891	0.7	0.944	0.733	0.868	0.825	0.715	1.014	0.727	1.079	0.655	1.063
3	3	2	-0.7	0.004	-0.027	0.05	-1	1	0.891	0.612	0.838	0.612	0.704	0.832	0.754	0.924	0.789	0.647	1.01	0.764	0.868	0.741	1.014
2	-3	0	3.9	0.025	-0.014	0.07	0	1	0.746	1.077	0.684	1.082	0.743	0.866	1.098	0.752	0.86	0.948	0.659	0.914	0.811	0.661	0.967
2	2	0	3.2	0.013	-0.049	0.07	-2	-1	1.065	0.764	0.975	0.86	0.651	0.795	0.924	0.786	0.889	0.914	0.647	0.873	0.625	0.6	1.002
2	-1	2	2.7	0.001	-0.026	0.029	0	-1	0.87	1.038	0.727	0.866	1.077	0.996	0.633	1.004	0.635	0.887	0.745	0.911	0.829	0.663	0.905
1	3	2	2.9	-0.019	-0.044	0.058	0	1	0.969	0.659	0.84	0.784	1.079	1.051	0.789	0.967	0.844	0.83	0.786	1.067	0.758	0.627	1.022

Table 10 Continued. NOLH Design

3	-2	0	-0.4	-0.1	0.014	0.044	0	2	1.063	0.664	0.741	1.047	0.967	1.061	0.661	0.805	0.92	0.952	0.719	0.69	1.045	0.819	0.737
2	4	-1	0.6	-0.096	0.035	0.058	-2	0	0.6	0.957	0.928	0.854	1.096	1.077	0.692	0.604	0.975	1.026	0.723	0.793	1.02	0.686	0.629
3	-1	2	-1.9	-0.091	0.037	0.094	-1	-2	1.016	0.69	0.762	0.901	0.786	0.643	0.961	0.998	0.633	1.034	0.682	0.659	0.961	0.653	0.705
1	4	3	-0.6	-0.082	0.028	0.06	-1	1	0.608	1.018	1.094	0.655	0.784	0.6	0.952	0.893	0.807	0.913	0.688	0.6	0.854	0.68	0.815
2	-4	0	1.9	-0.063	0.048	0.089	0	0	0.959	0.639	0.674	0.946	0.608	1.012	0.702	0.663	0.991	0.745	0.983	0.987	0.78	0.735	0.793
3	2	1	3.9	-0.06	0.037	0.079	-1	-1	0.739	1.045	1.088	0.832	0.76	1.038	0.69	0.842	1.006	0.614	1.071	1.061	0.651	0.778	0.832
1	-2	3	2.6	-0.065	0.028	0.027	-2	-1	0.987	0.645	0.657	0.996	1.041	0.786	1.079	1.063	0.774	0.627	1.004	0.991	0.696	0.823	0.635
2	1	2	3.6	-0.055	0.032	0.089	-1	2	0.737	0.928	0.879	0.6	0.928	0.823	1.075	1.034	0.748	0.61	1.034	0.862	0.87	0.856	0.762
1	-2	0	-2	0.011	0.004	0.042	-1	1	0.795	0.823	0.635	1.024	1.032	0.739	0.645	0.788	1.073	0.612	0.819	0.805	1.053	0.924	0.991
2	2	0	-1.8	-0.015	0.018	0.094	-1	-1	0.932	0.901	0.911	0.743	1.067	0.602	0.797	0.834	1.032	0.741	0.832	0.627	0.914	0.957	0.866
2	-2	2	-1.6	0.046	0.011	0.034	-1	-1	0.7	0.77	0.813	1.059	0.602	0.881	0.838	1.069	0.69	0.604	0.625	0.682	1.022	0.971	1.045
2	2	2	-1.3	0.015	0.02	0.045	-2	1	1.08	0.94	0.899	0.702	0.6	0.95	0.836	0.907	0.752	0.784	0.75	0.811	1.026	1.067	1.08
2	-4	-1	2.5	-0.003	0.034	0.039	-1	2	0.604	0.746	0.688	1.036	0.729	0.659	0.854	0.782	1.041	1.049	0.94	0.877	0.602	0.995	0.924
3	3	-1	2.4	0.048	0.025	0.076	-1	-2	0.93	1.049	0.907	0.803	0.664	0.778	0.727	0.627	0.891	1.1	0.922	0.836	0.666	0.934	1.096
3	-4	3	2.6	0.014	0.017	0.082	-1	-2	0.645	0.762	0.825	1.063	0.969	1.096	0.955	1.014	0.629	0.889	0.821	1.086	0.698	1.082	1.032
3	4	3	2.2	0.041	0.004	0.04	-2	2	1.01	0.914	1.057	0.793	0.897	0.93	0.977	0.87	0.737	0.899	0.944	0.913	0.764	0.905	0.875
3	-1	0	-0.5	-0.029	-0.021	-0.031	2	1	1.032	0.934	1.01	0.604	1.082	0.873	1.065	1.098	0.67	1.043	1.051	0.918	0.776	0.926	1.016
1	3	0	-0.9	-0.088	-0.008	-0.027	2	-1	0.813	0.78	0.647	1.094	1.055	0.989	1.016	1.094	0.688	1.063	0.934	0.905	0.705	0.916	0.858
2	-2	2	-1	-0.079	-0.007	-0.034	2	-1	0.901	1.094	1.059	0.631	0.782	0.61	0.766	0.711	1.086	0.905	0.866	1.045	0.721	1.053	0.901
2	2	3	-1.4	-0.047	-0.047	-0.042	2	1	0.655	0.83	0.629	1.03	0.762	0.764	0.856	0.649	1.1	0.799	0.918	0.983	0.7	0.879	0.914
2	-3	0	2.2	-0.033	-0.033	-0.003	1	1	0.926	0.893	1.047	0.735	0.674	0.985	0.969	0.969	0.735	0.805	0.635	0.625	1.051	0.952	0.922
2	3	0	2.8	-0.048	-0.008	-0.043	1	-1	0.84	0.698	0.739	0.973	0.756	1.094	1.063	0.875	0.762	0.672	0.789	0.672	1.071	1.061	0.909
2	-2	2	1.8	-0.099	-0.019	0.012	1	-2	1.038	0.911	0.916	0.717	1.073	0.743	0.848	0.653	0.959	0.639	0.788	0.686	1.1	0.969	0.936
2	3	3	3.5	-0.077	-0.021	-0.002	1	1	0.625	0.686	0.799	0.952	0.977	0.838	0.768	0.713	0.967	0.772	0.725	0.702	1.063	0.998	1.079
2	-4	1	0.9	0.014	-0.021	-0.047	1	1	0.686	0.948	0.87	0.819	0.965	0.641	0.87	0.891	0.713	0.618	0.836	1.006	0.612	0.803	0.739
3	3	0	-1.5	0.023	-0.012	0.017	0	0	0.955	0.795	0.608	0.979	0.993	0.653	1.092	0.916	0.705	0.78	0.901	0.893	0.745	0.77	0.774
1	0	3	-1.2	0.024	-0.045	0.01	2	-1	0.629	0.903	0.889	0.7	0.682	0.967	0.77	0.754	0.909	0.653	0.938	0.856	0.604	0.838	0.663
1	1	2	0.1	0.034	-0.013	0.007	1	2	1.004	0.616	0.807	1.09	0.774	0.909	0.784	0.625	1.039	0.659	0.83	1.004	0.799	0.711	0.715
1	-3	1	1.3	0.005	-0.001	0	1	2	0.688	1.069	0.864	0.614	0.721	0.635	0.871	1.006	0.623	1.059	0.825	0.731	0.971	0.649	0.623
2	1	-1	1.9	0.021	-0.04	0.023	2	0	0.952	0.856	0.735	0.942	0.614	0.78	0.928	0.887	0.772	1.022	0.621	0.809	1.094	0.801	0.657
3	0	2	4	-0.004	-0.009	0.016	1	-1	0.672	0.827	1.034	0.616	0.948	1.004	0.672	0.78	1.047	1.018	0.721	0.799	0.844	0.891	0.746
1	3	2	3.1	0.037	-0.005	-0.028	2	1	0.918	0.784	0.827	0.985	0.83	0.971	0.866	0.764	0.957	0.897	0.729	0.631	0.989	0.756	0.625

Table 10 Continued. NOLH Design

1	-1	1	-0.3	-0.056	0.002	0.001	1	2	0.873	0.641	0.932	0.666	0.885	1.079	0.75	1.049	0.684	0.971	0.727	0.942	0.664	0.67	1.055
1	0	-1	0.3	-0.037	0.042	-0.001	1	0	0.711	0.891	0.78	0.95	1.088	0.87	0.713	1.053	0.641	0.938	0.616	0.924	0.663	0.829	1.061
3	0	1	-1.7	-0.036	0.036	-0.018	1	0	1.039	0.805	1.08	0.707	0.768	0.774	1.038	0.827	1.051	0.893	0.807	0.985	0.682	0.694	0.897
1	3	1	0.3	-0.095	0.015	-0.038	1	1	0.803	1.043	0.698	1.018	0.801	0.702	0.993	0.846	0.996	0.946	0.827	1.063	0.616	0.789	0.983
1	-4	0	1	-0.075	0.005	-0.045	2	1	0.877	0.791	1.006	0.663	0.868	0.893	0.696	0.971	0.651	0.631	0.948	0.629	0.965	0.725	0.883
3	1	1	3.4	-0.037	0.015	-0.024	1	-1	0.692	0.862	0.616	1.098	0.821	0.993	0.688	0.996	0.707	0.797	0.959	0.707	1.024	0.682	1.02
1	-2	3	1.5	-0.054	0.049	-0.009	1	0	0.946	0.629	0.952	0.68	1.022	0.829	0.914	0.698	1.02	0.856	1.049	0.768	1.043	0.75	1.082
2	1	2	1.3	-0.057	0.035	0.002	1	2	0.733	1.08	0.758	0.995	0.893	0.694	0.901	0.682	1.088	0.67	0.871	0.725	0.934	0.721	1.057
2	-2	0	-0.2	0.007	0.026	-0.049	0	1	0.786	0.75	1.051	0.78	1.071	0.741	0.623	0.844	0.721	0.84	0.645	1.051	0.76	1.057	0.768
1	2	1	0.5	-0.007	0.032	-0.033	1	-1	0.94	1.02	0.614	0.877	0.864	0.631	0.762	1.067	0.858	0.789	0.77	1.038	0.805	1.096	0.766
1	-3	2	0.6	0.042	0.033	-0.021	0	-1	0.791	0.661	0.897	0.766	0.745	0.924	0.936	0.62	0.936	0.717	0.606	0.87	0.717	0.909	0.727
2	1	2	-1.8	-0.006	0.039	0.019	1	1	1.024	1.034	0.719	0.905	0.725	0.965	0.981	0.678	0.913	0.838	0.743	0.965	0.748	0.866	0.61
3	-1	0	3	-0.024	0.02	-0.016	1	0	0.649	0.696	0.885	0.741	0.739	0.84	0.67	1.036	0.799	0.93	1.069	0.813	0.887	0.961	0.653
1	4	1	1.5	0.035	0.03	0.014	1	-1	0.844	0.969	0.737	1.041	0.702	0.846	0.815	1.09	0.795	1.038	1.022	0.657	0.932	1.004	0.688
1	-2	1	2.1	-0.012	0.014	-0.037	1	-2	0.836	0.635	1.067	0.83	0.86	1.018	1.041	0.795	0.954	0.965	0.916	0.645	0.913	1.094	0.836
2	1	3	2.3	-0.018	0.041	-0.04	0	0	0.903	0.879	0.663	0.928	0.981	0.901	0.996	0.727	1.057	0.934	0.899	0.604	0.911	0.889	0.772
3	-3	0	-2	-0.049	-0.038	0.056	2	0	0.893	1.053	0.791	0.825	0.963	1.063	1.034	0.659	0.75	0.967	0.924	0.729	0.743	1.036	0.809
3	3	1	-1.3	-0.051	-0.034	0.037	0	-1	0.762	0.674	0.926	1.032	1.01	0.885	1.086	0.817	0.729	0.95	0.883	0.778	0.795	0.883	0.807
1	-2	3	-0.9	-0.068	-0.039	0.036	1	-2	1.049	1.051	0.602	0.69	0.715	0.789	0.649	0.942	0.932	1.016	1.032	0.834	0.715	0.864	0.7
2	1	3	0.7	-0.088	-0.045	0.095	1	2	0.694	0.6	0.856	0.961	0.625	0.725	0.682	0.938	1.043	1.02	0.991	0.766	0.643	0.955	0.846
1	-2	-1	2.6	-0.095	-0.019	0.075	1	1	1.018	1.063	0.778	0.647	0.717	0.969	0.959	0.791	0.692	0.69	0.698	1.082	1.014	0.907	0.784
2	0	-1	1.4	-0.074	-0.045	0.037	2	-2	0.612	0.748	0.977	0.981	0.705	0.913	0.895	0.719	0.813	0.725	0.61	0.909	0.928	0.852	0.649
2	-4	2	3.5	-0.059	-0.009	0.054	0	0	0.957	0.868	0.731	0.709	0.905	0.723	0.639	0.897	1.038	0.782	0.637	0.903	0.899	0.936	0.848
3	3	1	3.6	-0.048	-0.018	0.057	1	1	0.752	0.745	0.934	0.852	1.014	0.625	0.78	0.991	0.955	0.705	0.746	0.967	1.028	1.098	0.711
1	-2	-1	0	0.049	-0.048	0.057	1	1	0.633	0.918	0.77	0.821	1.094	0.825	0.875	0.739	0.776	0.633	1.043	0.803	0.694	0.799	0.895
2	1	0	-0.1	0.033	-0.005	0.043	0	-2	1.09	0.643	0.95	1.012	0.907	0.627	0.881	0.641	0.87	0.649	0.887	0.842	0.834	0.797	0.957
2	-4	2	-0.7	0.021	-0.01	0.092	0	-1	0.815	0.887	0.797	0.768	0.797	1.084	0.7	0.877	0.877	0.846	0.793	0.641	0.723	0.612	0.911
3	3	2	-1.5	-0.019	-0.012	0.044	1	1	0.973	0.819	1.063	0.844	0.764	1.028	0.61	0.985	1.014	0.629	1	0.875	0.719	0.772	1.008
3	-2	0	3.8	0.016	-0.016	0.026	1	0	0.825	0.842	0.639	0.713	0.791	0.657	1.088	0.799	0.76	0.932	0.791	0.883	0.948	0.674	1.094
2	3	0	2.9	-0.014	-0.001	0.085	1	-1	0.996	0.717	0.846	1.006	0.698	0.668	0.873	0.838	0.832	1.004	0.862	1.09	0.858	0.608	0.873
1	-1	2	2.4	0.037	-0.006	0.038	0	-2	0.653	1	0.834	0.745	1.059	0.899	0.84	1.012	0.985	1.057	0.711	0.852	0.903	0.709	0.955
1	1	3	1.9	0.04	-0.036	0.032	1	1	1.079	0.768	0.881	0.858	1.061	0.981	0.737	0.852	1.034	1.055	0.608	0.996	1.047	0.684	0.95

Table 10 Continued. NOLH Design

2	-1	0	-1.9	-0.081	0.016	0.029	1	0	0.985	0.788	0.645	0.737	0.889	1.086	0.629	0.811	0.758	0.991	0.805	0.688	0.635	0.621	0.631
1	3	1	0.7	-0.077	0.018	0.088	1	0	0.639	0.899	0.868	0.909	0.942	1.039	0.778	0.674	0.604	0.873	0.758	0.602	0.791	0.651	0.813
1	-1	1	0.4	-0.084	0.029	0.079	2	-1	1.041	0.608	0.776	0.723	0.817	0.709	0.913	1.092	0.944	1.098	0.702	0.772	0.688	0.846	0.752
1	0	2	0.3	-0.092	0.042	0.047	1	1	0.618	0.959	1.049	1.079	0.649	0.62	0.926	0.932	0.854	0.866	0.618	0.78	0.608	0.715	0.76
1	-1	-1	2	-0.053	0.046	0.033	2	1	1.059	0.672	0.786	0.686	0.62	0.995	0.807	0.705	0.621	0.727	1.1	0.93	0.975	0.827	0.659
1	1	1	1.1	-0.093	0.032	0.048	1	-2	0.735	1.067	0.877	1.067	0.891	0.897	0.756	0.672	0.801	0.616	0.965	1	1.073	0.645	0.674
1	-4	1	1.4	-0.038	0.023	0.099	0	0	0.92	0.725	0.676	0.635	0.846	0.664	1.032	0.926	1.026	0.774	0.936	1.057	0.996	0.672	0.721
3	0	1	3.1	-0.052	0.016	0.077	2	0	0.805	0.883	1.096	0.862	0.989	0.754	1.084	0.911	1.002	0.625	0.996	0.84	0.918	0.641	0.704
1	-1	0	-1.3	0.047	0.05	0.064	0	2	0.784	0.678	0.729	0.661	1.02	0.848	0.76	0.612	0.766	0.743	0.661	0.612	0.774	0.918	1.01
1	1	-1	-1.1	-0.017	0.039	0.073	2	0	1.034	1.098	0.991	0.948	1.084	0.758	0.678	0.801	0.803	0.809	0.692	0.741	0.661	0.981	1.088
3	-2	1	-1.3	-0.01	0.031	0.074	0	0	0.758	0.84	0.668	0.797	0.647	0.938	0.989	1.01	1.084	0.885	0.768	0.664	0.709	0.977	0.952
1	4	2	-1.7	-0.007	0.004	0.084	1	0	0.866	1.008	1.03	0.883	0.663	1.045	1.082	1.03	0.916	0.711	0.754	0.739	0.848	1.084	0.871
3	-3	-1	2.1	0	0.027	0.055	0	2	0.829	0.829	0.7	0.711	0.746	0.7	0.647	0.618	0.778	0.987	0.905	1.034	0.885	1.086	0.946
2	4	0	3.7	-0.023	0.007	0.071	1	-2	0.934	0.963	0.944	0.913	0.827	0.842	0.653	0.815	0.62	0.877	1.086	1.002	0.875	0.973	1.059
2	-3	3	1.5	-0.016	0.041	0.046	2	-2	0.657	0.604	0.659	0.807	1.065	0.895	0.905	0.993	1.004	0.944	0.92	0.989	1.077	1.022	1.098
2	3	3	2.1	0.028	0.043	0.087	0	2	0.879	0.993	0.957	1.057	0.913	0.954	0.975	1.02	0.852	1.008	1.098	0.948	0.969	0.938	0.823
0	3	1	1.7	-0.006	0.04	0.1	2	-1	0.719	0.793	0.631	0.692	0.77	0.797	0.823	0.629	0.618	0.686	0.739	0.721	0.746	0.788	0.696
-1	-1	2	3.7	0.008	0.003	0.096	1	0	0.913	0.971	1.1	1.043	0.856	0.612	0.631	0.668	0.602	0.776	0.889	0.719	0.807	0.86	0.725
-1	1	-1	1.4	0.044	0.031	0.091	2	1	0.702	0.723	0.664	0.672	1.069	1.016	0.883	1.065	1.022	0.721	0.641	0.676	0.618	0.754	0.608
0	-3	1	1.8	0.01	0.025	0.082	2	-1	1.069	0.991	1.082	1.077	0.922	0.891	0.995	1.1	0.989	0.608	0.67	0.705	0.823	0.717	0.797
0	0	1	0.4	0.039	0.029	0.063	1	-2	0.643	0.627	0.76	0.639	0.852	0.68	0.674	0.657	0.739	1.065	0.928	1.022	1.03	0.746	0.77
0	-1	3	-1	0.029	0.041	0.06	2	1	1.02	0.981	1.02	0.954	1.057	0.813	0.791	0.821	0.786	1.045	1.036	1.053	1.09	0.885	0.616
-2	1	1	-1.3	-0.023	0.002	0.065	0	1	0.602	0.735	0.754	0.76	0.672	1.055	1.057	0.93	1.09	0.998	0.844	1.08	1.008	0.752	0.801
0	-4	0	0.4	0.039	0.024	0.055	1	0	0.832	0.866	1.004	0.926	0.813	1.053	0.965	1.016	0.907	0.94	1.024	1.079	1.061	0.713	0.735
-2	0	3	1.8	-0.042	0.029	0.061	2	-1	1.073	0.715	0.829	0.815	0.692	0.928	0.803	0.748	0.77	0.909	0.694	0.635	0.713	1.034	1.049
0	-3	2	2.3	-0.094	0.011	0.035	0	2	0.801	0.942	0.979	1.075	0.666	0.879	0.821	0.655	0.727	1.012	0.848	0.737	0.809	0.858	0.987
-1	3	1	3.8	-0.034	0	0.096	0	2	0.922	0.705	0.705	0.801	0.924	0.651	0.985	0.86	0.864	1.036	0.815	0.606	0.862	1.09	0.969
-2	-3	-1	2.4	-0.045	0.017	0.065	0	0	0.819	0.846	1.09	0.918	0.959	0.817	0.899	1	1.018	0.907	0.731	0.756	0.741	0.993	0.971
-1	4	2	-1.6	-0.039	0.03	0.047	1	-1	0.983	0.704	0.621	0.836	1.006	0.934	0.729	0.639	0.702	0.819	0.952	1.02	0.93	0.94	1.039
-2	-2	2	-1.2	-0.076	0.03	0.098	0	1	0.776	0.989	0.936	0.93	0.901	1.034	0.811	0.772	0.754	0.821	0.858	1.084	0.907	1.032	1.073
-1	1	-1	0.9	-0.082	0.003	0.064	0	1	0.883	0.733	0.623	0.674	0.655	0.752	1.02	1.079	0.871	0.661	1.02	0.871	0.883	0.825	1.053
0	-2	0	-1.6	-0.04	0.022	0.091	1	-2	0.606	0.864	0.987	0.889	0.688	0.784	0.954	0.965	0.879	0.836	0.993	0.926	1.055	1.012	1.1

Table 10 Continued. NOLH Design

-1	0	2	2.7	0.035	-0.013	0.046	1	-1	0.854	0.926	0.661	0.764	0.766	0.768	1.014	0.676	0.655	0.758	1.028	0.661	0.803	0.92	0.879
0	-2	2	1.7	-0.02	-0.022	0.078	1	1	1.053	0.721	0.905	0.914	0.838	0.686	1.043	0.692	0.676	0.842	0.897	0.75	0.756	1.08	0.756
-1	2	1	1	0.022	-0.046	0.081	1	1	0.721	0.961	0.678	0.649	0.946	0.864	0.793	0.983	0.969	0.606	1.073	0.651	0.69	1.069	0.707
-1	-2	0	2	0.012	-0.023	0.067	2	0	1.002	0.61	1.028	1.004	0.987	1.024	0.743	0.955	0.883	0.694	1.08	0.653	0.614	0.932	0.664
0	0	2	-0.8	0.019	-0.043	0.098	2	-1	0.614	0.998	0.655	0.684	1.063	0.748	1.059	0.645	0.805	0.993	0.674	0.946	1.067	0.914	0.782
0	-1	1	-0.8	0.036	-0.036	0.08	1	1	0.971	0.621	1.075	1.092	0.842	0.737	0.809	0.721	0.723	0.963	0.639	1.092	0.973	0.893	0.788
0	2	1	0.8	-0.022	-0.002	0.067	1	1	0.709	1.047	0.686	0.778	0.748	1.092	0.651	1.039	1.028	0.829	0.737	1.008	0.963	1.063	0.741
-1	-1	0	-0.3	0.011	-0.043	0.072	1	0	0.842	0.852	0.967	0.971	0.727	0.94	0.6	1.086	1.069	1.002	0.774	0.938	0.922	0.868	0.83
-1	0	2	3.4	-0.068	-0.011	0.03	2	-2	0.911	1.016	0.746	0.627	0.805	0.983	0.983	0.76	0.834	1	0.854	0.815	0.659	0.676	1.086
0	-2	3	1.2	-0.041	-0.046	0.053	2	1	0.707	0.727	0.842	1.08	0.75	0.856	0.858	0.797	0.664	0.817	1.038	0.832	0.62	0.87	0.977
-2	2	1	2.9	-0.026	-0.006	0.041	1	1	0.936	0.875	0.745	0.829	0.877	0.811	0.664	0.977	1.061	0.954	1.077	0.743	0.827	0.69	1.028
-1	-3	0	2.5	-0.05	-0.013	0.054	0	0	0.862	0.811	0.883	1.002	1.09	0.721	0.752	0.881	1.055	0.996	0.891	0.674	0.684	0.625	1.067
-1	3	3	-0.8	-0.07	-0.009	0.075	1	0	0.975	0.987	0.715	0.789	1.024	1.002	0.868	0.864	0.637	0.731	0.823	0.954	0.938	0.733	0.981
-1	-2	1	-1.4	-0.07	-0.034	0.063	0	2	0.678	0.815	0.998	0.969	0.92	0.793	1.045	0.766	0.625	0.832	0.86	0.916	0.967	0.623	1.006
0	3	0	0.9	-0.029	-0.038	0.051	2	1	0.944	0.897	0.805	0.629	0.661	0.692	0.676	0.975	0.918	0.778	0.713	0.94	1.059	0.704	1.018
-1	0	0	-0.5	-0.058	-0.01	0.031	2	-1	0.811	0.67	0.918	1.049	0.709	0.633	0.813	1.057	1	0.668	0.797	0.881	1.069	0.758	0.92
0	1	2	1.2	-0.004	0.05	-0.035	1	-1	0.67	0.614	0.891	0.813	0.67	0.69	0.694	0.95	0.608	0.676	0.705	0.955	0.702	0.657	1.034
0	0	2	2.1	0.028	0.047	0.02	0	2	0.907	1.082	0.682	0.975	0.789	0.713	0.627	1.077	0.815	0.623	0.715	0.846	0.819	0.737	0.844
-1	3	0	1.6	0.031	0.044	-0.022	0	0	0.705	0.688	1.008	0.645	0.875	1.022	1.096	0.778	0.873	0.723	0.733	1.016	0.784	0.629	1.024
-1	-2	1	2.2	0.017	0.038	-0.012	2	0	1.026	1.075	0.707	0.895	0.871	0.973	1.094	0.737	0.983	0.621	0.633	0.952	0.754	0.813	1.03
0	1	1	-1	0.048	0.025	-0.019	1	0	0.623	0.754	1.073	0.827	0.834	0.629	0.698	0.959	0.719	0.961	1.047	0.668	1.032	0.692	0.942
0	-2	2	-0.5	0.03	0.023	-0.036	0	0	1.084	1.024	0.717	1.022	0.881	0.674	0.721	0.957	0.819	0.981	1.057	0.67	0.95	0.635	0.838
0	0	1	0	0.017	0.027	0.022	1	1	0.664	0.756	0.996	0.762	0.696	1.03	0.942	0.616	0.862	1.08	1.088	0.801	0.836	0.805	0.889
0	-1	0	0.8	0.022	0.02	-0.011	1	0	0.977	1.032	0.848	0.967	0.657	1.082	0.991	0.756	1.053	0.936	1.045	0.623	0.993	0.7	0.998
-1	2	3	1.8	-0.03	0.024	-0.018	1	-1	0.95	0.776	0.913	0.776	0.653	0.918	0.782	0.954	0.797	0.848	0.604	0.977	0.86	1.002	0.819
-1	-3	2	3.1	-0.053	0.007	0.009	0	2	0.848	0.922	0.711	0.944	0.684	0.955	0.62	0.871	0.606	0.875	0.684	0.879	0.821	1.041	0.84
-1	4	0	3.2	-0.041	0.048	0.024	2	2	0.928	0.694	0.948	0.809	1	0.756	0.967	0.832	0.875	0.985	0.686	0.973	0.621	1.045	0.637
-2	-3	0	2.7	-0.054	0.027	0	1	-1	0.809	1.088	0.862	1.088	0.996	0.868	0.946	0.776	0.911	1.053	0.69	0.936	0.832	0.959	0.686
-1	3	2	-1.9	-0.075	0.014	-0.02	0	-1	0.954	0.623	1.016	0.618	0.957	0.834	0.602	0.948	0.84	0.752	1.041	0.786	0.889	1.039	0.733
-1	-2	2	-1.2	-0.063	0.049	-0.02	2	1	0.635	0.936	0.725	0.84	1.049	0.905	0.776	0.914	0.811	0.786	1.053	0.827	1.075	1.1	0.698
-1	1	0	-0.7	-0.051	0.026	0.021	0	1	0.83	0.663	0.973	0.834	0.623	0.704	1.067	0.696	1.065	0.813	0.955	0.789	0.871	1.038	0.795
0	-3	0	-0.9	-0.031	0.044	-0.008	0	-1	0.731	1.041	0.86	0.916	0.621	0.649	0.911	0.733	0.856	0.87	0.914	0.633	0.942	1.073	0.678

Table 10 Continued. NOLH Design

-2	2	2	2.4	0.05	-0.014	0.006	0	-2	0.637	1.036	0.959	0.653	0.733	0.639	1.039	0.895	0.78	0.748	0.981	1.01	0.655	0.881	0.963
-1	-4	3	1.4	0.046	-0.035	-0.008	2	0	1.1	0.743	0.772	0.846	0.604	0.623	1.008	1.096	0.725	0.674	0.977	0.907	0.68	1.014	1.071
-2	1	0	3.9	0.041	-0.037	-0.044	1	2	0.684	1.01	0.938	0.799	0.914	1.057	0.739	0.702	1.067	0.666	1.018	1.041	0.739	1.047	0.995
0	-4	-1	2.6	0.032	-0.028	-0.01	1	-1	1.092	0.682	0.606	1.045	0.916	1.1	0.748	0.807	0.893	0.788	1.012	1.1	0.846	1.02	0.885
-1	4	2	0.1	0.013	-0.048	-0.039	0	0	0.741	1.061	1.026	0.754	1.092	0.688	0.998	1.038	0.709	0.955	0.717	0.713	0.92	0.965	0.907
-2	-2	1	-1.9	0.01	-0.037	-0.029	1	1	0.961	0.655	0.612	0.868	0.94	0.663	1.01	0.858	0.694	1.086	0.629	0.639	1.049	0.922	0.868

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APPENDIX F. MSM CLASS ORGANIZATION

Source Package

data.hist
- GainData.java
- LossData.java
- PromotionData.java

data.user
- Data.java
- DataByFy.java
- DataByFyGrade.java
- DataByFyMos.java
- DataSet.java
- DateFromSeq.java
- Distributions.java
- ForceControls.java
- InvSeq.java
- Inventory.java
- PayData.java
- RunArgs.java
- Sequence.java

main
- InputPrep.java
- InventoryDataTest.java
- Main.java
- Simulation.java

main.gui
- GenericAction.java
- MSMMenubar.java
- MSMToolBar.java
- MainGui.java
- WindowCloser.java

model.process
- Accessions.java
- Classification.java
- LatMove.java
- LatMovePromotions.java
- Losses.java
- Process.java
- Promote.java
- RegularPromotions.java
- Retention.java

model.structure
- GAR.java
- GarTre.java
- Marine.java
- Mos.java
- Network.java
- Node.java
- SNode.java

oracle
- OracleData.java
- OracleDateFromSeq.java
- OracleGains.java
- OracleInvSeq.java
- OracleLosses.java
- OracleODSEInventory.java
- OraclePromotions.java
- OracleSequence.java
- OracleTFDWInventory.java
- OracleTargetDistros.java

output
- AnnualStatsAggregator.java
- MonthlyStatsAggregator.java
- ResultsManager.java
- Writer.java

test
- TestCreateInputs.java
- TestPOI.java

utils
- ExcelFileType.java
- TabNotFoundException.java
- UnsupportedFileTypeException.java
- Utils.java
- Version.java

Test Package

utils
- ExcelFileTypeTest.java
- VersionTest.java

Libraries

Libraries
- Apache POI - poi-3.11-20141221.jar
- Apache POI - poi-ooxml-3.11-20141221.jar
- Apache POI - poi-ooxml-schemas-3.11-20141221.jar
- Apache POI - xmlbeans-2.6.0.jar
- Apache Commons Math - commons-math3-3.5.jar
- MersenneTwisterFast - MersenneTwisterFast.jar
- ojdbc - ojdbc14.jar
- JUnit 4.10 - junit-4.10.jar
- JDK 1.8 (Default)

Figure 53.   MSM Class Organization. Adapted from Garrick (2014).

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APPENDIX G. VALIDATION RESULT TABLES

Table 11.   NEAS Losses Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-54%	-49%	-45%	-43%	-47%
2005	-53%	-47%	-43%	-39%	-47%
2006	-59%	-56%	-51%	-51%	-51%
2007	-52%	-49%	-48%	-41%	-44%
2008	-53%	-54%	-46%	-42%	-47%
2009	-51%	-46%	-40%	-40%	-46%
2010	-43%	-35%	-32%	-35%	-44%
2011	-38%	-35%	-34%	-35%	-49%
2012	-33%	-33%	-31%	-43%	
2013	-33%	-32%	-41%		
2014	-33%	-44%			

Table 12.   Retired Losses Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-25%	-39%	-23%	-43%	-20%
2005	-18%	-29%	-13%	-39%	-32%
2006	-17%	-22%	-10%	-49%	-20%
2007	-10%	-22%	-26%	-40%	-30%
2008	-22%	-50%	-25%	-41%	-49%
2009	-16%	-11%	-11%	-53%	-31%
2010	18%	-8%	-26%	-29%	-58%
2011	-6%	-44%	-20%	-60%	-79%
2012	-22%	-26%	-47%	-81%	
2013	-5%	-48%	-71%		
2014	-33%	-72%			

Table 13.   Other Losses Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-29%	-11%	-19%	-12%	16%
2005	-8%	-20%	1%	47%	20%
2006	-40%	-23%	28%	8%	20%
2007	-6%	74%	82%	112%	123%
2008	-22%	18%	49%	97%	73%
2009	-21%	-6%	27%	25%	68%
2010	3%	36%	62%	116%	62%
2011	7%	11%	74%	43%	5%
2012	-5%	31%	23%	-9%	
2013	6%	-3%	-21%		
2014	6%	-23%			

Table 14.   EAS Losses Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-6%	-3%	7%	11%	-49%
2005	-4%	-2%	14%	29%	-53%
2006	-7%	4%	32%	24%	-55%
2007	-2%	19%	23%	11%	-58%
2008	-8%	-6%	-5%	-5%	-57%
2009	-15%	-19%	-9%	-10%	-50%
2010	-16%	-12%	-4%	-6%	-56%
2011	-10%	-10%	-1%	-17%	-28%
2012	-4%	-3%	-10%	1%	
2013	-6%	-18%	2%		
2014	-22%	-12%			

Table 15.   Aggregated Gains Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	2%	-41%	-34%	-42%	-38%
2005	-8%	-40%	-46%	-38%	-26%
2006	1%	-52%	-38%	-19%	49%
2007	-28%	-52%	-25%	46%	63%
2008	13%	-10%	84%	120%	243%
2009	16%	34%	77%	197%	253%
2010	66%	41%	153%	209%	237%
2011	14%	39%	87%	107%	43%
2012	46%	59%	80%	29%	
2013	16%	29%	-10%		
2014	19%	-23%			

Table 16.   Accession Gains Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-100%	-28%	14%	-4%	-29%
2005	-100%	-5%	-1%	10%	-7%
2006	-100%	-20%	8%	36%	-32%
2007	-100%	0%	37%	18%	-10%
2008	-100%	4%	2%	29%	-16%
2009	-100%	-17%	27%	24%	-64%
2010	-100%	26%	35%	-24%	-49%
2011	-50%	30%	-18%	-5%	-33%
2012	-5%	-21%	3%	-9%	
2013	-19%	-6%	-7%		
2014	-24%	-19%			

Table 17.   Promotions to E-2 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-40%	-68%	-20%	-5%	-30%
2005	-44%	-60%	-11%	-12%	-19%
2006	-42%	-62%	-17%	-1%	-2%
2007	-43%	-55%	-4%	21%	-2%
2008	-44%	-63%	-3%	9%	-1%
2009	-41%	-64%	1%	19%	-26%
2010	-44%	-41%	21%	-4%	-37%
2011	-21%	-15%	-2%	-14%	-18%
2012	3%	-18%	-10%	1%	
2013	-5%	-11%	-1%		
2014	-6%	-16%			

Table 18.   Promotions to E-3 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-11%	-69%	-42%	-4%	-13%
2005	-10%	-69%	-28%	-8%	-12%
2006	-10%	-67%	-32%	-8%	1%
2007	-10%	-67%	-24%	5%	12%
2008	-10%	-70%	-33%	-1%	2%
2009	-10%	-68%	-31%	5%	3%
2010	-13%	-64%	-10%	12%	-29%
2011	-5%	-37%	-2%	-21%	-19%
2012	-1%	-10%	-26%	-9%	
2013	-1%	-21%	-12%		
2014	-4%	-20%			

Table 19.   Promotions to E-4 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-61%	-46%	-18%	-27%	-20%
2005	-67%	-20%	-24%	21%	-38%
2006	-62%	-33%	16%	7%	-50%
2007	-66%	9%	4%	-6%	-41%
2008	-67%	-25%	-36%	-24%	-73%
2009	-60%	-40%	-28%	-48%	-55%
2010	-63%	-24%	-42%	-34%	-53%
2011	-40%	-35%	-24%	-29%	-41%
2012	-41%	-16%	-19%	-18%	
2013	-23%	-20%	-11%		
2014	-25%	-22%			

Table 20.   Promotions to E-5 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-94%	-65%	-42%	-51%	-15%
2005	-93%	-51%	-44%	-7%	-9%
2006	-88%	-58%	-6%	-3%	-23%
2007	-89%	-20%	1%	-9%	-5%
2008	-82%	-39%	-49%	-24%	-68%
2009	-68%	-50%	-16%	-59%	-44%
2010	-84%	-27%	-57%	-42%	-70%
2011	-49%	-50%	-20%	-51%	-59%
2012	-69%	-25%	-42%	-49%	
2013	-31%	-37%	-30%		
2014	-31%	-39%			

Table 21.   Promotions to E-6 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-96%	-54%	-43%	-36%	-2%
2005	-93%	-56%	-18%	-3%	-5%
2006	-77%	-32%	10%	-4%	-40%
2007	-73%	-4%	6%	-42%	0%
2008	-44%	-11%	-45%	-8%	-49%
2009	-29%	-43%	3%	-52%	-9%
2010	-44%	4%	-32%	1%	-74%
2011	-29%	-41%	17%	-65%	-47%
2012	-43%	14%	-48%	-40%	
2013	19%	-50%	-21%		
2014	-8%	-19%			

Table 22.   Promotions to E-7 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-91%	-66%	-43%	-37%	21%
2005	-88%	-65%	-11%	12%	-19%
2006	-79%	-39%	31%	-30%	-39%
2007	-78%	7%	-13%	-48%	11%
2008	-50%	-31%	-42%	-1%	-41%
2009	-40%	-30%	24%	-43%	-16%
2010	-40%	30%	-10%	-6%	-55%
2011	-24%	-34%	0%	-59%	-42%
2012	-31%	-6%	-30%	-42%	
2013	11%	-35%	-17%		
2014	-23%	-30%			

Table 23.　Promotions to E-8 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-94%	-96%	-40%	-57%	67%
2005	-96%	-69%	-35%	45%	6%
2006	-90%	-61%	68%	-16%	-27%
2007	-90%	36%	22%	-44%	20%
2008	-42%	-16%	-32%	-4%	-32%
2009	-25%	-10%	42%	-29%	-6%
2010	-9%	48%	8%	0%	-20%
2011	-5%	-26%	4%	-27%	-30%
2012	-15%	-2%	9%	-37%	
2013	16%	4%	5%		
2014	-26%	-23%			

Table 24.　Promotions to E-9 Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-93%	-97%	-42%	-47%	125%
2005	-96%	-74%	-29%	101%	11%
2006	-92%	-72%	134%	-21%	13%
2007	-93%	74%	16%	-21%	33%
2008	-18%	-29%	-1%	-9%	-10%
2009	-6%	53%	45%	-6%	21%
2010	24%	38%	27%	3%	1%
2011	7%	-15%	18%	-26%	-5%
2012	5%	37%	23%	-22%	
2013	62%	5%	15%		
2014	-19%	-6%			

Table 25.　End Strength Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	-15%	-20%	-18%	-19%	-19%
2005	-17%	-18%	-19%	-19%	-15%
2006	-16%	-19%	-19%	-15%	-12%
2007	-19%	-19%	-15%	-12%	-6%
2008	-17%	-15%	-12%	-6%	0%
2009	-13%	-12%	-6%	0%	-2%
2010	-12%	-6%	0%	-2%	0%
2011	-6%	0%	-2%	0%	0%
2012	0%	-2%	0%	0%	
2013	-2%	0%	0%		
2014	0%	0%			

Table 26.   Retention Zone-A Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	3%	-6%	-6%	-49%	-90%
2005	-1%	-4%	-51%	-40%	-84%
2006	8%	-48%	-39%	-28%	-80%
2007	-42%	-36%	-32%	-23%	-68%
2008	4%	-3%	3%	38%	-43%
2009	11%	11%	84%	28%	-53%
2010	-2%	53%	24%	-7%	-41%
2011	55%	19%	-1%	11%	11%
2012	-2%	-18%	-2%	8%	
2013	-10%	6%	15%		
2014	21%	33%			

Table 27.   Retention Zone-B Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	5%	4%	31%	-3%	10%
2005	-4%	-10%	-8%	13%	11%
2006	-8%	-29%	23%	38%	57%
2007	-29%	-9%	46%	83%	36%
2008	9%	34%	117%	100%	97%
2009	18%	91%	121%	137%	168%
2010	59%	77%	131%	160%	128%
2011	37%	74%	136%	117%	80%
2012	41%	94%	113%	78%	
2013	55%	69%	83%		
2014	44%	51%			

Table 28.   Retention Zone-C Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	19%	34%	43%	-3%	9%
2005	22%	27%	1%	19%	31%
2006	17%	-4%	35%	58%	50%
2007	-12%	20%	69%	69%	22%
2008	16%	63%	95%	64%	35%
2009	28%	72%	60%	41%	55%
2010	36%	44%	42%	67%	110%
2011	10%	16%	57%	86%	64%
2012	-5%	48%	114%	86%	
2013	36%	123%	97%		
2014	92%	89%			

Table 29.   Retention Zone-D Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	4%	18%	42%	-11%	29%
2005	8%	33%	-4%	33%	77%
2006	18%	-7%	51%	98%	18%
2007	-17%	45%	116%	24%	34%
2008	31%	107%	43%	51%	31%
2009	65%	38%	55%	34%	18%
2010	12%	48%	37%	25%	75%
2011	24%	28%	38%	75%	75%
2012	8%	29%	96%	93%	
2013	12%	85%	123%		
2014	51%	101%			

Table 30.   Retention Zone-E Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	153%	183%	195%	75%	187%
2005	178%	188%	101%	214%	233%
2006	186%	116%	295%	309%	138%
2007	116%	300%	390%	184%	154%
2008	366%	451%	303%	209%	200%
2009	452%	303%	225%	209%	192%
2010	268%	243%	227%	213%	261%
2011	240%	244%	299%	313%	256%
2012	227%	287%	417%	312%	
2013	269%	407%	423%		
2014	370%	415%			

Table 31.   Retention Zone-Senior Enlisted Relative Error

	1yr-Forecast	2yr-Forecast	3yr-Forecast	4yr-Forecast	5yr-Forecast
2004	133%	112%	127%	-1%	398%
2005	121%	90%	22%	173%	116%
2006	106%	22%	302%	31%	43%
2007	26%	300%	92%	-4%	83%
2008	392%	161%	89%	98%	101%
2009	82%	52%	67%	12%	53%
2010	45%	58%	36%	15%	44%
2011	114%	91%	108%	60%	87%
2012	86%	105%	108%	46%	
2013	76%	101%	79%		
2014	128%	124%			

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