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THESIS

DESIGNING ECONOMICS EXPERIMENTS TO DEMONSTRATE THE ADVANTAGES OF AN ELECTRONIC EMPLOYMENT MARKET IN A LARGE MILITARY ORGANIZATION

by

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March 2001

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The Navy detailing process complicated and detailers spend many hours trying to assign sailors to jobs. There are many factors to be considered for each job assignment: sailors' preferences, commands' requirements and the numerous policies that affect both sailors and commands, manning priority levels etc. Often this process is fraught with subjectivities, as each resultant job assignment will vary, depending on the detailer making the assignment.

It is therefore timely to explore another way of doing business: a 2-sided matching process that considers sailors' preferences and commands' requirements and assigns sailors to jobs in an equitable and fair manner. This new process is better able to cope with the complexities of job detailing and other additional information requirements.

This thesis compares the differences between the current detailing systems and a 2-sided matching process, and presents the advantages of adopting the latter. This new way of doing business brings about major benefits for large organizations such as the US Navy.

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ABSTRACT

The Navy detailing process is complicated and detailers spend many hours trying to assign sailors to jobs. There are many factors to be considered for each job assignment: sailors' preferences (detailing), commands' requirements (placement) and the numerous policies that affect both sailors and commands, manning priority levels etc. Often this process is fraught with subjectivities, as each resultant job assignment will vary, depending on the detailer making the assignment.

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I. INTRODUCTION

A. OBJECTIVES

The Navy Personnel Command assigns over 100,000 Sailors annually using in excess of 200 Detailers. Detailers try to strike a balance between the commands' needs and the Sailors' preferences, which is inherently difficult to achieve. The current process utilizes the hierarchical planning method and unfortunately, this centralized labor-intensive detailing method leaves many stakeholders (e.g. Sailors, detailers, and commands) discontent and frustrated. In some instances, Sailors have chosen to separate from the Navy rather than accept undesirable orders, further decreasing retention rates. By the same token, some commands have been forced to receive less qualified Sailors to avoid vacancies in key positions, reducing mission effectiveness. The current Navy enlisted detailing process may be enhanced by a review of the actual detailing process. A new way of detailing could include the use of a 2-sided matching algorithm to match sailors to available jobs. Sailors could be given some form of control by ranking their preference over available jobs for their next rotation of jobs before applying for them. Commands could also rank their preference of certain attributes that they are looking out for in sailors in their list of available jobs. The 2-sided matching process can then perform a job match to assign sailors to jobs. This matching process may yield a higher level of utility for both sailors and commands, compared to the current detailing system. Some form of this is already present in the JASS system today.

Advances in Information Technology (IT) developments facilitate this form of electronic employment in large organizations. Large cost savings could result by removing the human element out of the loop. In addition, subjectivities on the part of the human detailers are eliminated. The detailing process could be more efficient and equitable using web-based markets and intelligent agents to assist Sailors and commands in finding one another in a distributed, electronic system. An electronic detailing system has the potential to enhance the various stakeholders' satisfaction through better job matching methods. Developing an electronic detailing system that will satisfy the needs of all stakeholders requires an intimate understanding of the current detailing process's positive and negative aspects. Knowing stakeholders' satisfactions and dissatisfactions with the current process will facilitate designing and executing a superior electronic detailing process.

The purpose of this research is to examine the limitations of job matching in the Navy, and to design an economics experiment to demonstrate the potential for an electronic employment market.

B. RESEARCH QUESTIONS

1. The Primary Research Question Is:

What form of electronic employment market can be designed for a military organization that will satisfy both sailor's preferences and the Commands' requirements?

2. Supporting Or Secondary Research Questions Include:

(1) How are personnel detailed in the USN, what are the limitations of this process, and how do these limitations affect enlisted personnel assignments?

(2) How can an agent-based electronic market help optimize job matching?

(3) What economics experiments can demonstrate the outcomes expected in both the current and proposed job-matching process?

(4) Based on the economics experiments, what advantages does electronic job matching offer enlisted sailors, commands and detailers?

(5) How will using an agent-based electronic employment market benefit both the organization and the individual?

C. SCOPE, LIMITATIONS AND ASSUMPTIONS

1. Scope

The scope includes:

(1) A literature and document review of the current Navy enlisted detailing process.

(2) Phone/personal interviews and PowerPoint reviews delineating steps within and flow of the current Navy enlisted detailing process.

(3) A review of survey data and PowerPoint briefings concerning Sailors' satisfaction or dissatisfaction with the current detailing process.

(4) Analysis of the current Navy enlisted detailing process to identify positive aspects that should be incorporated into a new web-based detailing system.

(5) Identifying the a few key attributes that are deemed important to both Sailors and Commands to be included in the design of the new detailing model.

(6) Formulating an economics experiment using the identified key attributes and performing this experiment on a group of personnel.

2. Limitations

Although every attempt was made to gather the most accurate data for the current Navy enlisted detailing process, there is neither a formal system to collect this information nor is there a way to gather only objective data; much of the information comes directly or indirectly from subjective interviews and briefings.

The design of this economics experiment is a simple and crude model to examine the feasibility of applying this new concept to the complicated process of detailing. There is no way to ascertain whether this concept will be bought in the first place. A major paradigm shift in thinking in the Navy needs to be accompanied by this new concept of detailing to enhance success.

3. Assumptions

This thesis assumes that the reader has a general knowledge of the current Navy enlisted detailing process. The reader is not expected to know the specific process, but it is assumed that the reader has some knowledge about the detailing system so that common acronyms and verbiage are not confusing.

D. METHODOLOGY

The methodology used in this research includes the following steps:

1. Conduct literature and Internet searches of books, magazine articles, PowerPoint briefings, and library information databases.

2. Identify the key attributes for use in the new system via phone and/or personal interviews with EPMAC and other agencies.

3. Design and conduct an economics experiment using the few identified key attributes.

4. Analyze the results of the new detailing process and compare with the current system.

5. Determine implications for the new future system.

E. ORGANIZATION OF THESIS

Chapter II will cover the current detailing process adopted by the US Navy. In addition, the strengths and shortcomings will be analyzed.

Chapter III will be the design and conduct of the new economics experiment, taking into account the identified key attributes.

Chapter IV will be the analysis of the results achieved from the conduct of the new economics experiment.

Chapter V draws final conclusions from the experiments conducted and recommend topics for future research.

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II. BACKGROUND - OVERVIEW OF THE EMPLOYMENT MARKETS

A. LABOR MARKET ECONOMICS

Market-based approaches to employee/employer matching rely on the interaction of labor demand and supply, and what is now textbook understanding of labor market economics (Ehrenberg and Smith 1997). On the demand side of the labor market are employers; while on the supply side of the market are workers and potential workers. The forces of demand and supply heavily influence the wage that prevails in a particular labor market.

The demand curve is typically downward sloping. Firms combine various factors of production - mainly capital and labor - to produce goods or services that are sold in a product market. Their total output and the combination of capital and labor depend on three forces - product demand, the amount of labor and capital they can acquire at given prices, and the choice of technologies available to them. When the wage is high, it is likely that the potential return per dollar invested in capital will be higher than labor. Thus the firm will continue to invest more in capital than labor until the equilibrium in return per dollar invested is reached. Thus at one end, high wages typically correspond to lower labor demand. On the other hand, should the wage be cheaper, the potential return per dollar invested in labor will yield higher return than capital. The logical firm will then invest more in labor, and less in capital. Thus lower wages will usually result in higher demand for labor. The market demand curve indicates how many workers the firm will be willing to hire at each wage level, holding all other variables (such as capital costs) constant[1].

[1] It is important to distinguish between a *shift* in a demand curve and *movement along* a curve. When the *wage* changes and other forces are held constant, one *moves along* the curve. However, when one of the *other forces* changes, the labor demand curve *shifts*. For example, the costs of capital decreases, the substitution effect will cause the labor demand curve to shift left, i.e. overall lowered demand for labor at any given wage point. On the other hand, lowered capital costs could also result in lower product pricing, thereby leading to higher demand. This scaling effect could potentially shift the labor demand curve right, i.e. higher demand for labor at any given wage point. How the demand curve shifts will depend on the juxtaposition of these two market forces.

The labor supply curve is usually upward sloping. If the wages in the other occupations are held constant, and the wages in our study market rise, we will expect more people to be willing to enter this market as their opportunity costs of not joining this market become higher due to the relative improvement in compensation. Therefore, when the wages are low, we expect to see a low labor supply (these are the enthusiastic people who really enjoy working in this particular environment), while high wages will usually result in a high labor supply (these are the people attracted to join the market due to better compensation relative to their other choices). The market supply curve indicates how many workers would enter the market at each wage level, holding the wages in other occupations constant.

The point where the labor demand and supply curve intersect is known as the *market-clearing wage* or *market equilibrium wage*. Figure 1 illustrates labor demand and supply curves for a representative labor market. The wage rate in this market tends towards its equilibrium value denoted by W*. The quantity of labor that employers are willing to hire at this wage rate exactly equals the quantity of labor that employees willingly supply (L*). Anyone that wants to work in the industry can find sufficient work and any firm that wants to hire employees can find adequate employees.

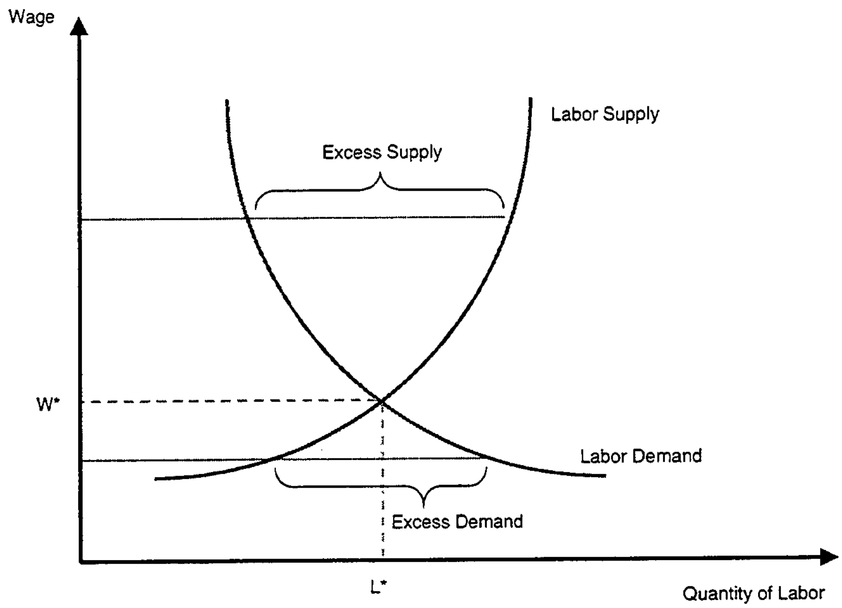

Figure 1: Market-Based Labor Markets

If the wage rate is below the equilibrium W*, demand for labor will *exceed* supply. At this point, employers will be competing for the few workers in the market and a shortage of workers will exist. The desire of the firms to attract more employees would lead them to increase their wage offers, thus driving up the overall level of wage offers in the market (upward pressure on wage rate towards W*).

As the wage rises, two things will happen. First, more workers will choose to enter the market and look for jobs (a movement upwards along the supply curve), and second, increasing wages would induce employers to seek fewer workers (movement downwards along the demand curve). If wages rise over W*, the supply will exceed demand. Employers will desire fewer workers than the numbers available. This will result in excess in supply. Employers soon realize that they can fill their positions with lower wages as eager applicants look for jobs. Some will be happy to accept the jobs at the lower wage rate, while others will leave the market (thereby movement downwards along the supply curve). Again, the forces of the market will tend to drive the wage towards the equilibrium wage W*.

A subtle but important aspect of equilibrium wage rates involves job amenities such as work environment, geographic location, commute, promotion potential, work content/challenge, and job satisfaction etc. In weighing employment benefits in one industry relative to alternative time uses (leisure and other jobs), job amenities are important considerations. If job amenities are particularly attractive in one industry, individuals will supply labor to that industry at relatively low wage rates; if job amenities are unpleasant, labor is only supplied at relatively high wage rates (Ehrenberg and Smith 1997). This is referred to as *compensating wage differentials*. For example, an engineer is likely to be paid more if he is required to perform arduous field work in third world countries versus his counterpart with the same qualifications in a comfortable office close to home. Holding other characteristics constant, individuals willing to work in an industry for relatively low wages either derive high utility from agreeable job amenities (e.g. flexible hours for a spouse with children), or are relatively weakly deterred by objectionable job amenities (e.g. a fit young adventurous individual working as a forest ranger).

Market-based labor markets balance demand and supply, ensuring equality between the quantities of labor demanded and supplied. To operate efficiently, employees must have complete information about relevant job opportunities, including salary, benefits and job amenities. To mimic the results of market-based labor markets, alternative labor market mechanisms must both balance demand and supply, and promote demand and supply efficiencies. To ensure demand and supply efficiency, labor assignments must reflect labor's relative value in alternative uses, employee capabilities and job preferences.

With regards to labor assignments, there are currently two modes prevailing in the matching people with jobs: 1) hierarchical planning and 2) distributed markets. Each has strengths and limitations, which will be discussed in the following sections.

1. Hierarchical Labor Market

Hierarchical labor markets assign individuals to jobs using a centralized process. Such assignments rely on administrative procedures to match individual capabilities and job requirements and to reflect both the job's relative priority and the individual's job preferences. There is no mechanism to automatically strike a balance between supply and demand efficiencies, as in market-based labor markets. At one extreme, employers can assign individuals to jobs with little regards to personal preferences. Employees can either accept the assignment or find another alternative occupation. This approach emphasizes the employer's performance (demand efficiency) at the expense of employee morale (supply efficiency). At the other extreme, employers can emphasize individual job preferences relative to job priority and the match between employee skills and job requirements. This emphasizes employee morale at the expense of employer performance. Criticisms against hierarchical labor markets concern their inability to ensure demand and supply efficiencies, inherent equilibrium conditions in market-based labor markets. This inability reflects both information requirements and asymmetric incentives (profits vs. morale).

Demand and supply efficiencies are particularly important for closed systems with a constrained labor supply. In the military, wages are uniform across jobs requiring similar skills and experience (no compensating wages). As a result, the cost of assigning labor to one use is the loss of output in the best alternative unfilled use for that labor (opportunity cost); salaries and benefits are irrelevant in measuring labor costs. If labor assignments don't maximize demand and supply efficiencies, the system wastes resources by applying them to less valuable jobs, and reduces job satisfaction, morale and retention, by assigning labor to jobs that are relatively less desirable with no compensating wage differential.

The Department of Navy (DoN) uses a centralized, hierarchical labor market to match enlisted sailors jobs. On the demand side, Navy commands identify open positions. Job vacancies are compared to projections of available personnel. Typically, the number of positions to be filled exceeds the supply of available personnel. Therefore, the Navy develops a Navy Manning Plan (NMP) that spreads the labor shortage across all commands, on a "fair-share" basis. The Navy then prioritizes job vacancies based on each command's mission, current staffing levels, and several other relevant characteristics. This process attempts to distinguish between high and low valued demands for labor, to mimic demand efficiency in market-based economy.

On the supply side, available personnel are categorized according to their qualifications (ratings), including skills, experience, education/training, career path, etc. Similar skill groups are arranged in communities (e.g. electronics, supply, machinists). Each community has a detailer charged with matching personnel to jobs. Sailors seeking job assignments can express their personal preferences to the detailer. The detailer is responsive to job vacancy priority ratings, but there is some room for discretion in tailoring job assignments to meet the sailors' personal preferences (supply efficiency). Supply efficiency is subordinate to demand efficiency in this process.

DoN's hierarchical labor market is further complicated because enlisted sailors change jobs every two to three years. Thus, the centralized detailing process reassigns between one third and one half of the enlisted force every year. This adds a time dimension to this process that is more critical than in typical civilian markets. The Navy begins identifying job vacancies and available personnel as early as nine months in advance. Time also affects the job vacancy priority rating. More imminent vacancies receive a higher priority than similar but more distant vacancies.

DoN fills billets (i.e. jobs) according to a predetermined priority ranking until the labor supply is exhausted, and demand efficiency is emphasized over supply efficiency. In market-based labor markets, equilibrium wage rates automatically performs functions; wages adjust until there is no excess supply or demand for labor, and employees voluntarily choose their preferred job, considering both relative wages (compensating wage rates) and job amenities. In DoN's hierarchical labor market, wage rates do not increase to limit the demand for labor to the available supply, so commanders are frustrated they can't fill vacant positions. Similarly, wages do not adjust across job assignments to account for job amenities, and assignments do not fully incorporate the sailor's job preferences. Predictably, both commanders and enlisted sailors voice dissatisfaction with the current hierarchical labor market.

2. Distributed Markets – Two-Sided Matching Markets

A market-based approach supports unrestricted, point-to-point matching between potential employees and outside employers. In this scenario, the potential for problematic information overload can be high, and employee turnover incessant.

Unlike fast-paced IT firms in Silicon Valley, wage rates for military personnel are set by fiat and adjust very slowly to supply- or demand-driven pressures. At least in the short term, DoN cannot rely on spot labor markets for filling its key jobs with qualified people. Indeed, without its current, hierarchical detailing system, the Navy would find it very difficult to fill many of its important jobs. Yet the Navy could also benefit from the efficiencies associated with market-based systems. A two-sided matching market assigns individuals to jobs when there are several possible employers and employees. The matching algorithm balances the employers' and employees' preferences, but it can produce assignments that give priority to either employers or employees. As such, the algorithm specifically addresses both demand and supply efficiency. Unlike hierarchical systems, matching markets balance both employers' and employees' preferences. This effectively matches job requirements and employee capabilities, and systematically helps obviate many supply side problems, including employee dissatisfaction, low morale and retention. This improves both demand and supply efficiency relative to hierarchical labor markets. Two-sided matching markets also are responsive enough to keep pace with the extreme periodic job rotations effected routinely by the Navy. But such matching markets lack the automatic dynamic response of market-based systems, and the opportunity for side agreements that circumvent the system can be administratively cumbersome. Unlike market-based systems, two sided matching markets provide some centralized control through the clearinghouse, and periodic matching can dampen the high rates of employee turnover now experienced in high technology industries.

The balance between demand and supply preferences depend on the matching algorithm. It is important that the matching process recognize job priorities, a function performed by detailers in DoN's hierarchical process.

In our thesis, our focus will primarily be on, the design of an economics experiment that can demonstrate the differences between the current system and the agent based two-sided matching systems. These results can be used to analyze and evaluate the potential benefits and limitations of using a two-side matching algorithm in assigning DoN personnel.

B. OVERVIEW OF THE CURRENT NAVY ENLISTED DETAILING PROCESS

1. Organization Structure

The Navy's Manpower, Personnel, and Training processes include Manpower Requirements, Manpower Programming, Personnel Planning and Personnel Distribution. This thesis will concentrate on the Personnel Distribution process, specifically the Enlisted Distribution System (EDS). The EDS consists of a distribution triad: allocation, placement, and assignment, as depicted in Figure 2 below.

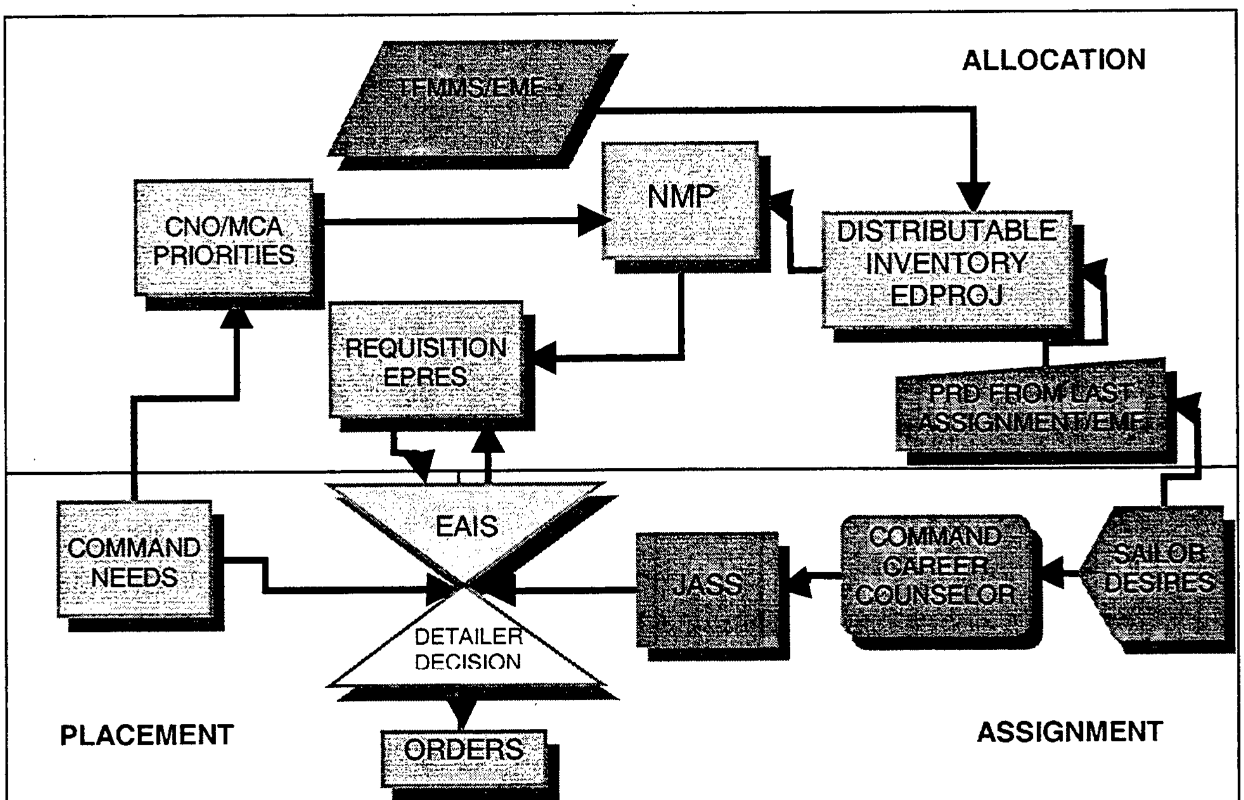

Figure 2: From: Manpower, Personnel, & Training PowerPoint Brief, From CDR Bill Hatch, 16 May 2000

The overall distribution goal is to ensure what is commonly referred to as the "four rights" or "R4:" the right Sailor with the right training occupying the right billet at the right time. The focus in this thesis will be on the assignment process within the distribution triad, which is commonly called "detailing", for active duty enlisted Sailors.

The allocation process initially separates distributable and non-distributable personnel inventory. Distributable inventory includes everyone who is not a student or in a Transient, Patient, Prisoner, or Holdee (TPPH) status. Students also referred to as Awaiting Instruction (AI) and TPPH personnel are non-distributable and are included in the Individuals Account (IA). This process is depicted as Figure 3 below.

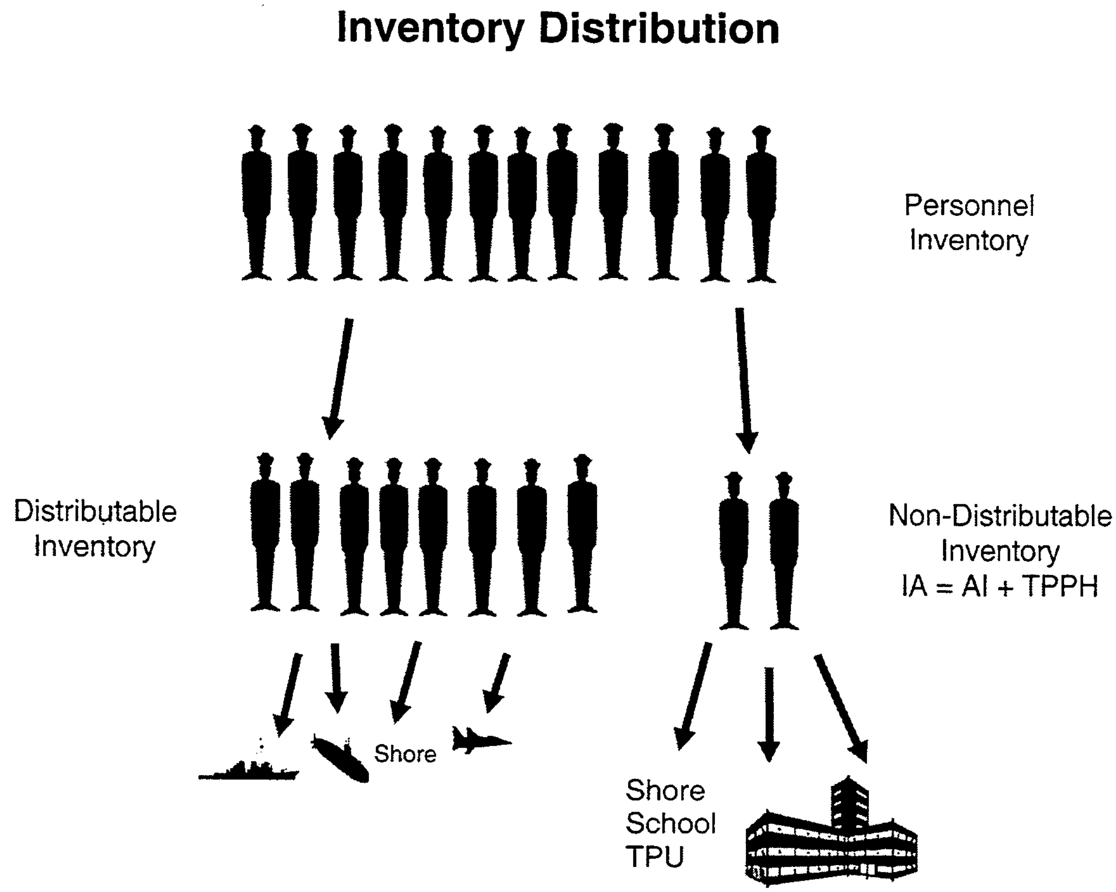

Figure 3: From: Manpower, Personnel, & Training PowerPoint Brief, From CDR Bill Hatch, 16 May 2000

The four Manning Control Authorities (MCAs) are then apportioned distributable inventory in accordance with Chief of Naval Operations (CNO) priorities. The four MCAs include Commander in Chief, U.S. Pacific Fleet (CPF); Commander in Chief, U.S. Atlantic Fleet (CLF); Commander, Navy Personnel Command (CNPC); and Commander, Naval Reserve Forces (CNRF). The CNO and MCAs establish priority manning for distributable inventory. Allocation, placement, and assignment of distributable inventory are depicted in Figure 4 below. Each level of distribution is discussed in further detail following the chart.

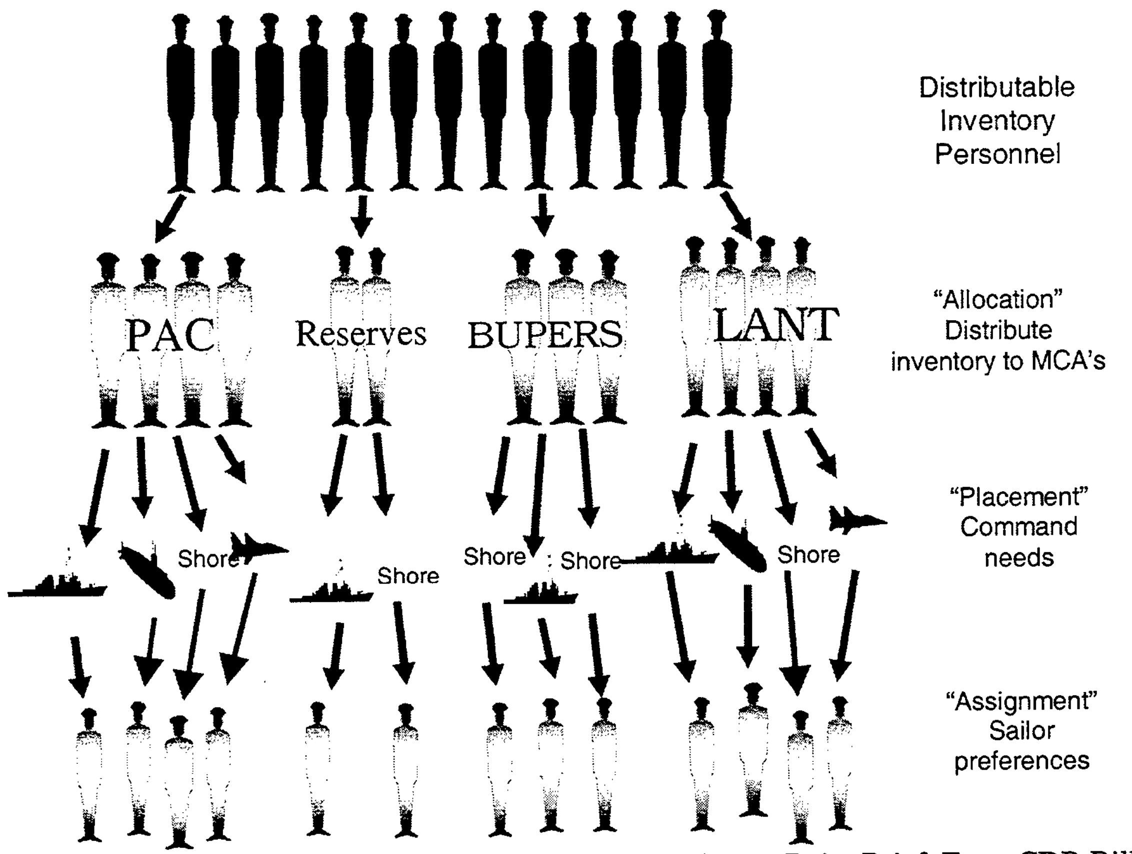

Figure 4: From: Manpower, Personnel, & Training PowerPoint Brief, From CDR Bill Hatch, 16 May 2000

From Figure 4 above, the three distribution levels for distributable inventory are clear. The allocation process apportions distributable inventory to the four MCAs based on CNO priorities. Then, the placement process ensures that command needs are addressed. Finally, the assignment process considers the Sailors' preferences. These processes are further explained.

CNPC is involved with the allocation process. It is organized into different branches or departments, commonly referred to as Personnel or "Pers" codes. The Distribution Management, Allocation, Resources and Procedures department (Pers 45) is responsible for allocation supervision and ensures a prioritized balance of distributable personnel to both sea and shore activities. Pers 45 personnel use the Enlisted Distributable Projections System (EDPROJ), a computer program which measures current strength against current billets for statistical purposes, and measures the projected strength nine months in the future against the projected billet time frame. EDPROJ receives data from two information systems, the Total Force Manpower Management System (TFFMS) and the Enlisted Master File (EMF), to determine where available personnel should be assigned to ensure equitable allocation among CNO priorities and the four MCAs.

Pers 45 uses EDPROJ to measure current strength versus current billets and projected strength versus projected billets in the next nine months. The CNO determines CNO priority manning (Priority 1/2), which is transferred to EDPROJ to ensure that these priorities are accounted for before any other allocations are made. This resulting information is transferred from Pers 45 to the Enlisted Placement Management Center (EPMAC). (Hatch)

EPMAC uses the projected personnel from EDPROJ, coupled with MCA's prioritization manning algorithms and billet information from TFMMS to establish Navy Manning Planning (NMP) levels. NMP equitably distributes the projected personnel by rate (i.e. E3, E6, E9); rating (i.e. ABF, PN, EN); and Navy Enlisted Classification (NEC) code across all activities to ensure each command receives its "fair share" of distributable personnel. Distributing the projected enlisted inventory equitably across the four MCAs, EPMAC's goal as the command advocate is to ensure the right person with the proper occupational skills occupies the right billet on time.

The MCAs communicate with EPMAC to ensure that activities have the personnel they need to accomplish their missions. Depending on the command's operational schedule, special circumstances, or additional considerations, MCAs can adjust requisition priorities to meet individual command personnel needs. When activities need to increase manning above their NMP level for specific mission accomplishment, MCAs may designate Priority 3 manning requisitions within their areas of responsibility. Priority 3 requisitions are valid for up to one year, and they are automatically cancelled on 30 September, unless another specific date is authorized. Designating a requisition as Priority 3 indicates that the billet has a higher priority than other requisitions, but Priority 3 requisitions are not as high priority as the CNO Priority 1 and 2 requisitions. Requisition priorities are an important consideration during the assignment process. During the assignment process, Sailors are selected and assigned, commonly called "detailing," into high priority billets based on NMP. In other words, the assignment process matches "faces" with "spaces." "Faces" result from scheduled rotation or availability whereas "spaces" occur when the command has fewer projected assigned personnel than the NMP, producing a "requisition."

Requisitions are generated in the Enlisted Personnel Requisition System (EPRES) information system when a command's projected manning in a particular rating and rate (pay grade) falls below the projected NMP levels. The requisitions are then downloaded into the computer-based Enlisted Assignment Information System (EAIS), where the assignment officer, referred to as the detailer, can review them. Requisitions appear in priority order with the number one requisition being the highest priority billet to fill. CNO Priority 1 and 2 requisitions will appear at the top of the list immediately followed by the MCA Priority 3 requisitions.

The detailer represents the Sailors, or faces, in the Enlisted Distribution System. The detailer's goal is to cost effectively match Sailors with the necessary skill sets to the prioritized requisitions. Detailers employ EAIS to accomplish their difficult task of assigning available personnel to priority requisitions. Detailers view distributable inventory Sailors in EAIS nine months before completing their current tour of duty, i.e., their Projected Rotation Date (PRD). Non-distributable Sailors in the IA (students and TPPH) also appear in EAIS nine months prior to their PRD.

Once detailers have selected a Sailor for a particular requisition, they access the Orders Writing Screen (OM) to begin the order writing process. Once orders are electronically assigned, before actual orders are written, EPMAC reviews those orders for personnel E6 and above for quality of fit. EPMAC has the authority to veto preliminary assignments between detailers and petty officers first class and above. This ensures that the detailers' assignment best matches Sailors to jobs. EPMAC placement specialists can veto orders that fail to meet fleet readiness manning and balance, even if the orders are exactly what the E6 or above Sailor requested. EPMAC provides a sanity check on orders to ensure the fleet receives the Sailor it needs. Once approved by EPMAC, if applicable, the Sailor receives written orders. Essentially, the allocation, placement, and assignment processes work in concert to meet the Navy's readiness priorities.

2. Navy Assignment From A Micro Perspective

The Navy's centralized system to reassign personnel among different duty types has two objectives. First, the assignment system must optimize readiness and stability for both afloat and ashore activities. Secondly, the assignment system must provide equal opportunity for personnel to serve in their desired duty. In theory, the task appears rather simple; in practice, balancing the Navy's needs with the Sailor's desires involves complex, time-consuming tradeoffs often requiring the Sailor to either accommodate or acquiesce one or more facets of their desired job assignment. Sailors may have to accept a different type duty, location, billet, or ship than they originally preferred.

Detailers rely on myriad information systems as well as personal rating knowledge to direct personnel into prioritized, available billets. EAIS, which displays requisitions by priority, is their primary information system. If personnel require training en route to their new command, detailers use the Navy Training Reservation System (NTRS) database to obtain class quotas and ensure requisite training is accomplished. (Hatch)

Currently, there is no single tool to help the detailers "mentally juggle" diverse policies, procedures, and information to ensure that the right Sailor with the necessary occupational skills is assigned to the right job on time. Detailer decisions, primarily subjective, may not always result in the best match for the Navy and/or the Sailor. Detailers must consider numerous, often changing, policies and procedures promulgated by the DoD, CNO, MCA, and CNPC when matching personnel to billets. (Cunningham, Hatch) Furthermore, Sailors have their own unique preferences, goals, and personal needs that detailers must consider. Detailers continually struggle to manage the Navy's requirements and the Sailor's wishes.

The detailer's primary consideration is whether the Sailor possesses the occupational skill set the billet requires. This consideration must be balanced with the detailer's next concern: conserving Permanent Change of Station (PCS), or transfer, funds. Detailers must minimize monetary expenditures yet maximize the effective use of personnel abilities and qualifications. To assist with this tasking, detailers can review Sailor's qualifications in EAIS. EAIS will give the detailers pertinent information for reassignment decisions such as number of dependents, NECs, End of Active Obligated Service (EAOS) date, Projected Rotation Date (PRD), current duty station and assignment history or Armed Forces Qualification Test (AFQT) scores, which are used to determine reassignments.

Detailers also take into account spreadsheets containing the average PCS expenditures based on the Sailor's pay grade, location, and number of dependents. Detailers tenaciously match Sailors to jobs to the best of their ability. Their job is made more difficult because EAIS is only about 80 percent correct in characterizing service members' skills and the average PCS expenditures are only updated biennially. (Detailer Interviews)

If the Sailor does not possess the billet's required skill level, detailers may consider training alternatives. Depending on class quota availability and training expenditure levels, the detailer can offer the constituent training en route. Using NTRS, the detailer immediately reserves the Sailor's quota; ensuring required training is accomplished prior to the member's arrival at the new command.

Detailers must also maintain fleet balance by ensuring that enlisted personnel are equitably distributed to all activities among the MCAs by rate, rating, and NEC in proportion to the Enlisted Master File (EMF) delineated by the NMP. The requisition's priority and gapped billets require detailer's focus to ensure that priority-designated jobs are filled first and that face-to-face turnover occurs whenever possible.

Acting as career counselors, detailers must advocate various duty assignments for service members. Detailers must ensure that personnel have the opportunity for advancement experience and rating excellence, and that they equitably share any existing hardship duty. Other factors requiring the detailer's attention are the member's Projected Rotation Date (PRD) and sea/shore rotation cycle. When considering personnel for overseas assignments, detailers must also follow Congressional policy which states that active duty members may not be assigned on land outside the United States or its territories and possessions, until they have had twelve weeks of basic training or its equivalent. Therefore, detailers can assign new enlistees overseas only after their initial basic training.

For personnel who have family members in primary or secondary school, detailers attempt to schedule transfers during school breaks, to minimize school schedule disruption as practicable. Additionally, military couples must be co-located if at all possible. Gender is another factor requiring the detailer's careful attention; females must be near adequate medical treatment facilities during pregnancy and females have fewer potential duty assignments (e.g. no female billets are available on submarines or Navy Sea, Air, Land (SEAL) billets and certain ships are not configured for female Sailors).

Given these considerations, balancing the Sailor's desires with the Navy's priorities requires the detailer's meticulous attention and genuine concern. Sailors' personal concerns include such items as home ownership, spouses' careers, children's stability, and location preference. Each is a valid concern that detailers should address. Furthermore, an entire detailing division is dedicated to handling service members' special assignments such as Humanitarian Assignments (HUMS) or Exceptional Family Member (EFM) personnel. Currently, approximately 294 enlisted detailers manage nearly 330,000 Sailors' careers. (Cunningham)

To improve decision-making efficiency and effectiveness, the Job Advertising and Selection System (JASS) was developed. JASS is an on-line information and decision support system for Sailors, Command Career Counselors (CCCs), and detailers. At their convenience, Sailors around the world view and apply for the posted prioritized billets. Prior to JASS, Sailors had to negotiate with detailers via the telephone. This first-come, first-serve process forced Sailors to make hasty decisions over the phone and compelled detailers to assign personnel to billets when they were not the "best qualified" or least costly move. Furthermore, Sailors assigned to ships, remote locations, or night shifts often did not have the opportunity to contact their detailers for jobs upon initial opening. (Burlingame) As a result, they often got "stuck" with less desirable billets. These Sailors were frustrated by their disadvantaged position. In short, the Navy's priorities and Sailor's desires were not optimized before JASS was introduced in 1995.

JASS permits Sailors to view jobs available in their pay grade and rating or Navy Enlisted Classification (NEC) code. Inconvenient phone calls to the detailers and snap decisions without family involvement are minimized. View-only JASS, available via Bureau of Personnel (BUPERS) Access, allows Sailors to see, but not apply for, all available jobs in the current requisition. Any service member, enlisted or officer can use view-only JASS to see the available jobs by rate, rating, and NEC. (Burlingame) With this initiative, Sailors can go on-line in the comfort of their homes or workstations to explore available jobs. Sailors can see available positions, research alternatives, and discuss options with family. Ultimately, this information system allows Sailors to make informed, sagacious decisions regarding their next duty assignment. Only Command Career Counselors, or those designated by their Commanding Officer as career counselors, have the access to make job applications. Command Career Counselors are involved for two reasons. First, they ensure that the Sailors are eligible and qualified for the positions to which they are applying. Secondly, Command Career Counselors are fully engaged in the advisory role for Sailors' careers. View-only JASS offers Sailors flexibility and convenience.

Command Career Counselors aboard naval vessels use JASS Client. They download bi-monthly data for the latest information cycle and jobs available. Using the ship's Standard Automated Logistics Tool Set (SALTS) via International Maritime Satellite (INMARSAT) communication capabilities, the CCC can download the most recent JASS information, including the latest requisitions, via File Transfer Protocol (FTP) program. The Command Career Counselor then works off-line with JASS Client, assisting Sailors with their job applications. Before the end of the application cycle, usually five days, the Command Career Counselor uploads all Sailors' billet applications for their detailers' review. Currently, WEB JASS is being introduced as an improved tool for Command Career Counselors. (Burlingame) This simplifies their access to JASS information by allowing downloads and uploads directly from the Internet, to ships or stations with Internet access.

Using JASS Client or WEB JASS, the Command Career Counselor helps Sailors apply for up to five different jobs in preference order during a two-week requisition cycle. Because Sailors only have approximately five days to submit applications to the detailer before requisitions close, Sailors at sea, in remote locations, or working odd shifts have the opportunity to apply for the same jobs to which shore Sailors conveniently apply. No longer is the detailing process a first-come, first-serve assignment process. Detailing involves batch processing, thereby leveling the playing field for all Sailors. (Burlingame; Hatch)

When requisitions close, detailers spend approximately four days reviewing constituents' desires and matching the best-qualified person to the available positions based on the Navy's needs and the Sailor's desires and/or qualifications. Allowing batch-process detailing, JASS ensures a greater probability of efficient, effective Sailor-to-job pairing. Once a Sailor is assigned to an available position and new requisitions are uploaded from NMP, the detailer releases new billets on JASS, restarting the two-week cycle.

One drawback to JASS is that Sailors expect to be assigned to their number one billet application, even though they apply for up to five different jobs. Frequently Sailors are not selected for their most preferred job, so detailers receive numerous phone calls or emails from disgruntled constituents requesting explanations and/or recommendations. (Marquez, O'Brien) At the beginning of every two-week requisition cycle, the detailers can expect to answer these phone calls or emails. Detailers can give Sailors career advice on steps to make them more marketable for their desired positions.

Despite some disadvantages, JASS is generally advantageous for detailers as well. Detailers have the highest level of JASS access. They can view jobs, apply for jobs, and select Sailors to fill jobs. Since JASS in not compatible with EAIS, detailers must laboriously hand-transfer information from JASS into EAIS, and vice versa. On the other hand, JASS allows detailers to concentrate on actual assignments because it eliminates initial phone calls requesting available billet information. In addition, detailers can now select the "best qualified" Sailor for the job from several applicants rather than the first person who is able to contact the detailer, benefiting both the Navy and the Sailor. Helping detailers optimize the Navy's priorities and grant Sailor's desires, JASS is a step toward connecting detailers, Command Career Counselors, and Sailors in this ever increasingly automated world.

3. The Need For Alternative Approach

The Navy must ameliorate the cumbersome, random detailing process to create incentives for junior and senior Sailors to remain in the Navy. In recent years, the civilian unemployment rate has declined to four percent, a 30-year low. First-term Navy attrition approached 40 percent in 1998-1999, the highest in history. (Moniz "Military Uses Net") Considering the booming economy and the potentially disruptive military life, we must take steps to ensure that people are not leaving the military in search of alternative occupations. The Navy's centralized, labor-intensive detailing process often disappoints its Navy customers, including both commands and Sailors. In addition, the detailing process is such a significant factor in Sailors' careers that it may potentially reduce Sailor morale and retention. If left unchecked, a deficient detailing process could lead to Sailors' substandard performance and poor fleet readiness. (Gates) Sailors today expect fast answers and quick explanations for why they were not selected for the first-choice job or what their next career-enhancing move should be.

The Navy-wide Personnel Survey found that approximately 78% of enlisted Sailors have full-time employed spouses, a significant increase from previous years. (Kantor 1990-1997; Olmsted) In many instances, the spouse's career provides a larger family income than the Sailor's career. Thus, the Navy must allow and, indeed, encourage continued spousal employment by assisting Sailors to accommodate their spouse's career. Otherwise, assignment may have a direct bearing on whether Sailors decide to continue their Navy career. (McGrath)

A common complaint among Sailors using JASS is that their Command Career Counselor is not readily available to assist them with career advice or job applications. Very often Sailors resort to the former method of telephoning their detailer to get the perceived "inside scoop." Furthermore, despite being able to view available jobs on JASS, Sailors believe they will receive better or different job options by directly contacting the detailer. (Detailer Questionnaires; Holden; O'Brien)

The Enlisted Distribution System may wish to examine lessons learned from the Commander, Navy Recruiting Command (CNRC), which now employs online recruiting to enlist new troops. CNRC is meeting Generation Y on its own turf, the Internet, and the military's recruiting targets are being met. Vice Admiral Ryan, Chief of Naval Personnel, recently commented that cyber-recruiting could be more effective than the old method of stalking malls and high schools for enlistees. (Moniz "Military Engaged") The detailing process must follow suit and start offering job searches and selections via the Internet. Although not problem free, JASS is an excellent first step, but needs to go further to balance the Navy's needs and the Sailor's desires.

Two-sided matching labor markets offer the potential to address these concerns experienced by the commanders and the sailors. This thesis will focus on the design and use of economics experiments to demonstrate the current system of job detailing and examine the potential benefits and limitations of applying agent-based two-sided matching to DoN's hierarchical labor market.

C. INTELLIGENT AGENT TECHNOLOGY

1. A Classical Algorithm For Stable Marriage

In the article by Irving, Leather and Gusfield, they discussed an algorithm that can be employed to achieve stable marriage matching of sample size n. A stable matching is a complete matching of men and women such that no man and woman who are not partners both prefer each other to their actual partners under the matching.

In an instance of the stable marriage problem, each n men and n women lists the members of the opposite sex in order of preference. Gale and Shapely gave an efficient algorithm for finding such a match. This classical algorithm normally yields what is called the male optimal solution, with the property that every man has the best partner that he can have in any stable marriage. If applied with the roles of men and women interchanged, the algorithm will yield the female optimal solution, which similarly favors the women. The achievement of best possible partners by the members of one sex results in the members of the opposite sex having their worst possible partners.

MATCHING ALGOTHM MAN BIAS

MAN	PREFERENCE							
1	3	1	5	7	4	2	8	6
2	6	1	3	4	8	7	5	2
3	7	4	3	6	5	1	2	8
4	5	3	8	2	6	1	4	7
5	4	1	2	8	7	3	6	5
6	6	2	5	7	8	4	3	1
7	7	8	1	6	2	3	4	5
8	2	6	7	1	8	3	4	5

WOMAN	PREFERENCE							
1	4	3	8	1	2	5	7	6
2	3	7	5	8	6	4	1	2
3	7	5	8	3	6	2	1	4
4	6	4	2	7	3	1	5	8
5	8	7	1	5	6	4	3	2
6	5	4	7	6	2	8	3	1
7	1	4	5	6	2	8	3	7
8	2	5	4	3	7	8	1	6

MAN	PREFERENCE							
1	3	1	5	7	4	2	8	6
2	6	1	3	4	8	7	5	2
3	7	4	3	6	5	1	2	8
4	5	3	8	2	6	1	4	7
5	4	1	2	8	7	3	6	5
6	6	2	5	7	8	4	3	1
7	7	8	1	6	2	3	4	5
8	2	6	7	1	8	3	4	5

WOMAN	PREFERENCE							
1	4	3	8	1	2	5	7	6
2	3	7	5	8	6	4	1	2
3	7	5	8	3	6	2	1	4
4	6	4	2	7	3	1	5	8
5	8	7	1	5	6	4	3	2
6	5	4	7	6	2	8	3	1
7	1	4	5	6	2	8	3	7
8	2	5	4	3	7	8	1	6

MAN	PREFERENCE							
1	3	1	5	7	4	2	8	6
2	6	1	3	4	8	7	5	2
3	7	4	3	6	5	1	2	8
4	5	3	8	2	6	1	4	7
5	4	1	2	8	7	3	6	5
6	6	2	5	7	8	4	3	1
7	7	8	1	6	2	3	4	5
8	2	6	7	1	8	3	4	5

WOMAN	PREFERENCE							
1	4	3	8	1	2	5	7	6
2	3	7	5	8	6	4	1	2
3	7	5	8	3	6	2	1	4
4	6	4	2	7	3	1	5	8
5	8	7	1	5	6	4	3	2
6	5	4	7	6	2	8	3	1
7	1	4	5	6	2	8	3	7
8	2	5	4	3	7	8	1	6

MAN	PREFERENCE						
1	3	1	5	7	4		
2	1	3	4	8	7		
3	7	4	3	1	2	8	
4	5	8	6	1	4	7	
5	4	2	8	7	3	6	5
6	6	5	7	4	3		
7	8	6	2	3	4	5	
8	2	7	1	3	5		

WOMAN	PREFERENCE						
1	4	3	8	1	2		
2	3	7	5	8			
3	7	5	8	3	6	2	1
4	6	4	2	7	3	1	5
5	8	7	1	5	6	4	
6	5	4	7	6			
7	1	4	5	6	2	8	3
8	2	5	4	3	7		

Figure 5: Male and Female Preference Lists

The classical algorithm for a solution to a stable marriage instance is based on a sequence of "proposals" from the men to the women. Each man proposes, in order, to the women on his preference list, pausing when a woman agrees to consider his proposal, but continuing if a proposal is either immediately or subsequently rejected. When a woman receives a proposal, she rejects it if she already holds a better proposal, but otherwise agrees to hold it for consideration, simultaneously rejecting any poorer proposal that she may currently hold. (A "better" proposal means a proposal from some man higher in the woman's preference list.)

Hence after first round, it can be seen from the example in Fig 5, men [2] and [7] would have been rejected by the first woman on their preference list. The match [2,6] and [7,7] are considered unstable matches and shaded gray. Men [2] and [7] will now propose to the women second on their preference list, highlighted in white. 3 scenarios can happen:

(1) **Women accept proposals, rejecting proposals they held earlier from other men**. The other man would have to "move on" and propose to the woman in second choice. The process of proposal is repeated again for the rejected men.

(2) **Women reject the proposals from men [2] & [7]**. The unstable matches would be shaded gray and the men move on to propose to the women next on their list.

(3) **Women accept the proposal, with no prior proposal from other men**. The process represents a stable match when nobody gets rejected.

The process is repeated until all matches are stable. In this example, the stable match scenario occurs when men [2] & [7] propose to their second choice women.

Thus, it can be shown that the sequence of proposals will result in every woman holding a unique proposal, and that the proposals held constitute a stable matching (A similar outcome results if the roles of males and females are reversed, in which case the resulting stable matching may or may not be the same as that obtained from the male proposal sequence). Two fundamental implications of this initial proposal sequence are:

(1) If m proposes to w, then there is no stable matching in which m has a better partner than w;
(2) If w receives a proposal from m, then there is no stable matching in which w has a worse partner than m.

These observations suggest that we should explicitly remove m from w's list, and w from m's, if w receives a proposal from someone she likes better than m. These are shaded in gray in the example in Fig.5 and the resulting list is called the shortlist (male-oriented) for the given problem instance, with the following properties:

(1) If w does not appear on m's shortlist, then there is no stable matching in which m and w are partners.
(2) W appears on m's shortlist if and only if m appears on w's, and is first on m's shortlist if and only if m is last on w's.
(3) If every man is paired with the first woman on his shortlist, then the resulting match is stable; it is called the male optimal solution, for no man can have a better partner than he does in this matching, and indeed no woman can have a worse one.
(4) If the roles of males and females are interchanged, and if every woman is paired with the first man on her (female-oriented) shortlist, then the resulting matching is stable; this would be a female optimal solution, for no woman can have a better partner than she does in this matching, and indeed no man can have a worse stable match.

2. Relevance To This Thesis

The classical algorithm will be the matching algorithm used in the economics experiment for matching between the sailors and different commands. As in the illustration above, the current assignment system can be mimicked by replacing the males with commands, and females with sailors available for assignment. This will result in a command biased match, reflecting the current detailing process where detailers try to assign sailors to prioritized jobs while considering the sailor's preferences. Our thesis will attempt to demonstrate the potential difference in the utility function between sailors-biased and command-biased match achieved in the current detailing system and the possibility of improving these utility figures when increasing the batch size of available sailors to be assigned for jobs.

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III. DESIGNING THE ECONOMICS EXPERIMENT

A. INTRODUCTION

The design of the economics experiment to simulate the current detailing system went through a several rounds of iteration. In its final version, only 2 attributes were considered in the ranking of sailors' preference of job. Similarly, only 2 attributes were considered from the commands' perspective to rank their choice of sailors for the jobs available. From the earlier rounds of the economics experiments, it was assessed that an average human detailer could only cope with this level of details in assigning sailors to jobs. The detailers would be overloaded with information if there were more than two preference attributes. The arrangement and presentation of attributes of command and sailor preference also went through several rounds of iteration, to facilitate absorption of information by the detailers (experiment subjects). The abbreviations and wordings were also changed several times to ensure that they were termed as closely as possible to those used in the detailing community.

The command-preferred attributes used in the actual experiment are <u>NEC Training Level and Sailor's Past Performance</u> while the sailor-preferred attributes are <u>Sailor's Preferred Location and Promotion Prospects of the Job</u>. Different preference levels were randomly generated and assigned to each of these attributes for both commands and sailors for the experiments. In conducting the experiment, detailers were allowed to assign sailors to jobs using their own standard of criteria.

In addition, the economics experiments on job assignment were conducted in varying sailor batch size and job availability. This was to simulate scenarios where sailors needing a new job reach the detailers as a batch. The detailers had to assign jobs to each batch before the next batch arrived. It was anticipated that higher overall utility could be derived with a larger sailor batch size than with smaller sailor batch size.

Similarly, a larger available pool of job was expected to naturally result an overall better job match than with a smaller pool of jobs.

Appendix A is the sailors' and commands' profile and Appendix B is the detailed set of experimental instructions that was used to conduct the economics experiments.

B. EXPLANATION OF UTILITY FUNCTION USED IN THE ECONOMICS EXPERIMENT

Preference List Algorithm

The sailor's individual utility is given by the Cobb Douglas utility function:

$$U_S = BPI^{\alpha_P} * L^{\alpha_{SPL}}$$

Where:

U_S = Utility of sailor

BPI^{α_P} = Sailor's derived utility from promotion prospects of billet

$L^{\alpha_{SPL}}$ = Sailor's derived utility from fit between sailor's preferred location (SPL) and actual billet location (BL)

$\alpha_P + \alpha_{SPL} = 1$

Sailor's derived utility from promotion prospects of billet. More demanding and high profile billets are likely to be more challenging to the sailors, and competent sailors who manage the job are more likely to be noticed and ranked higher. This elevates their chances for promotion and career advancement. This is captured by the Billet Promotion Index (BPI) of each requisition billet, ranging from 1 to 5, with 5 being the highest and 1 being the lowest chance of promotion on the job. How much utility a sailor derives from a billet that is likely to boost his career advancement and promotion prospects will depend on his weight α_P.

Promotion Prospect	Billet Promotion Index (BPI)
Excellent	5
High	4
Average	3
Moderate	2
Low	1

Sailor's derived utility from fit between sailor's preferred location and billet location. Sailors specify their preferred location by the index SPL. The billets specify their location by the index BL. If there is a match between SPL and BL, the Location Index L will be assigned the value of 5, otherwise L will be less than 5, as shown in the table below. The sailor will thus derive a higher level of utility for a successful location match. How much utility he derives from the match will depend on how much weight he assigned to location fit, specified by α_{SPL}.

Preferred Location	Billet Location	Location Index (L)
LANT CONUS	LANT Non-CONUS	3
	PAC CONUS	2
	PAC Non-CONUS	1
LANT Non-CONUS	LANT CONUS	3
	PAC CONUS	1
	PAC Non-CONUS	2
PAC CONUS	PAC Non-CONUS	3
	LANT CONUS	2
	LANT Non-CONUS	1
PAC Non-CONUS	PAC CONUS	3
	LANT CONUS	1
	LANT Non-CONUS	2

The agent will calculate the U_S each billet provides to each sailor, and rank profile the billets for each sailor based on decreasing Us. This is the Sailor's Preference List.

The command's individual utility is given by the Cobb Douglas utility function:

$$U_C = TL^{\beta_{TL}} * SPI^{\beta_{SPI}}$$

Where:

U_C	= Utility of command
$TL^{\beta_{TL}}$	= Command's derived utility on getting sailor of the desired trained level.
$SPI^{\beta_{SPI}}$	= Command's derived utility on getting a sailor of a higher performance rating.

$\beta_{TL} + \beta_{SPI} = 1$

Command's derived utility on getting sailor of the desired training level. Commands want to be assigned a sailor whose training level STL matches or is higher than the requirement of its billet BTL. If there is a perfect match between STL and BTL (i.e. STL >= BTL), the matched TL will be assigned a value of 5. Further deviations between STL and BTL will yield lower values of TL.

STL < BTL	TL
One level down	3.75
Two level down	2.50
Three level down	1.25

Having determined the value of TL for every eligible sailor for a particular billet, the agent then calculates the utility derived from a training level match. How much utility a command derives from training level matching will depend on the command's weight to training level matching, β_{TL}.

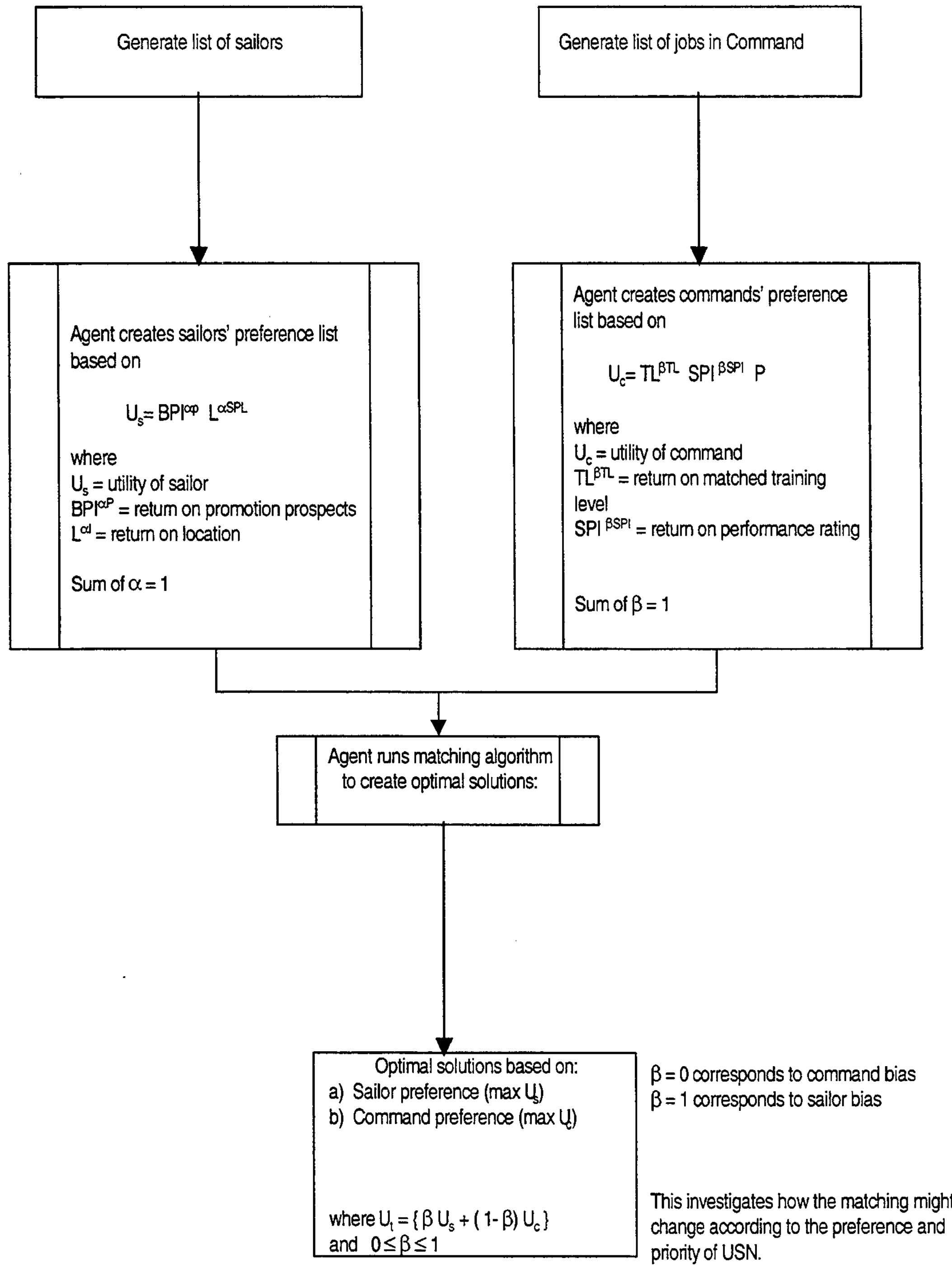
Command's derived utility from getting a sailor of a higher performance rating. Some commands will derive a higher utility from being assigned a sailor with a higher performance rating than others. The rating of sailor's performance ranges from 1 (not promote) to 5 (early promote). The command's derived utility will depend on how much weight the command has assigned to β_{SPI}.

Sailor Performance	SPI
Early Promote	5
Must Promote	3.75
Promote	2.5
Not Promote	1.25

C. COMPUTER MATCHING ALGORITHM

The flow of the computer-matching algorithm is shown in the diagram below. There are two types of algorithms available, namely sailor or command biased. The former will yield greater utility for the sailors on the whole while the latter will produce greater aggregate utility for the commands. There are many instances whereby both the sailor and command-biased algorithm would produce the same outcome but the explanation of such phenomena is outside the scope of this thesis study.

COMPUTER MATCHING ALGORITHM



1. Sailor-Biased Matching Algorithm

In this matching algorithm, the preference of the sailors is first taken into consideration when assigning jobs to sailors. When there is a conflict of choice, i.e. two or more sailors wanted the same job, the command preference is then used to decide which sailor gets the job. For example, if sailor #2 and #4 wanted job #5, and the command prefers sailor #2 to sailor #4, sailor #2 will be given the job. Sailor #4 will then has to move on to his or hers next preferred job.

2. Command-Biased Matching Algorithm

For the command-biased matching algorithm, the preference of the command is considered first. When there is a conflict of preference, the preference of the sailor will be used to decide which command gets the sailor, in the same manner as described above for sailor-biased matching algorithm.

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IV. FINDINGS

A. INTRODUCTION

After designing the economic experiments, the next step is to implement these experiments with a group of human subjects. Pre-tests were conducted to ensure that the instructions were clear and that the terms used made sense to the world of detailing. In addition, assistance from EPMAC was sought to ensure that the terms used fitted as closely as possible to the familiar terms to which detailers were exposed.

The first round of experiments was conducted on a group of Logistics Management students at Naval Postgraduate School (NPS). There were 18 officers in this group acting as detailers. The full range of 4 separate exercises was conducted.

The second round of experiments was conducted on a smaller group of actual detailers working in Millington, Tennessee with the assistance of Naval Personnel Research, Studies and Technology (NPRST). There were 6 detailers in this group. Due to the lack of time, only 2 exercises were conducted for this group. These consisted of matching 5 sailors to 8 jobs (with a batch size of 5) and matching 10 sailors to 12 jobs (with a batch size of 10).

B. RESPONSE DEMOGRAPHICS

The first group of subjects consists of officers from the US and other countries. In addition, these officers come from the various branches of service (Air Force, Army, Navy and Marine Corps). To ensure that officers from other countries (besides the US) understood the terms used in the experimental instructions, additional time was devoted to explain and clarify the instructions and the tasks expected of them. This varied and diverse group of officers brings with them their own unique experience with regards to detailing, having been detailed before at some point in their career. It is also noted that none of them has had actual detailing experience.

The second group of detailers consists of actual senior enlisted personnel working as detailers for the aviation community in Millington, Tennessee. They bring with them a whole depth of experience in the detailing world.

C. RESULTS

1. Results Of Exercise One: Matching 5 Sailors To 8 Jobs Using Batch Size Of 1

The detailed results are presented in Appendix C and summarized in chart 1 below. This exercise was only performed on the first group of 18 officers from NPS.

Maximum Sailor Utility by Detailer:	19.05
Minimum Sailor Utility by Detailer:	12.70
Average Sailor Utility by Detailer:	16.41
Standard Deviation:	1.777

Sailor Utility derived from 2-Sided Matching:

20.38 (Command-biased)
20.85 (Sailor-biased)
20.62 (Average)

Average Percentage Improvement: 20.38%[1]

It can be seen that the 2-sided matching algorithm results in a higher utility compared to that achieved by the human detailers. On average, the 2-sided matching results in 20.38% improvement. In

[1] A simple null hypothesis test was conducted to check the statistical significance of the difference between sailors' utility by human detailers and computer matching (using the average utility from Command and Sailor biased Algorithm). Using a confidence level of 95%, the null hypothesis was rejected. The difference in sailors' utility is significant.

addition, there is tremendous variability in performance across human detailers. The quality of assignment might well depend on the individual that happens to be assigned as the detailer.

2. Results Of Exercise Two: Matching 5 Sailors To 8 Jobs Using Batch Size Of 5

Two separate groups of subjects performed this experiment. The detailed results are reflected in Appendix C and summarized in chart 1. The summary is as follows:

(1) First group of 18 officers from NPS

Maximum Sailor Utility by Detailer:	19.47
Minimum Sailor Utility by Detailer:	12.85
Average Sailor Utility by Detailer:	16.85
Standard Deviation:	1.907

Sailor Utility derived from 2-Sided Matching:

20.38 (Command-biased)
20.85 (Sailor-biased)
20.62 (Average)

Average Percentage Improvement: 18.26%[2]

It can be seen that 2-sided matching results in a higher utility compared to the human detailers even when sailors arrive in batches. On average, the 2-sided matching results in 18.26% improvement over that achieved by human detailers. Furthermore, there is only a marginal improvement in average performance when the sailors are detailed in a batch vice first come, first served.

[2] A simple null hypothesis test was conducted to check the statistical significance of the difference between sailors' utility by human detailers and computer matching (using the average utility from Command and Sailor biased Algorithm). Using a confidence level of 95%, the null hypothesis was rejected. The difference in sailors' utility is significant.

(2) Second group of 6 detailers from Millington

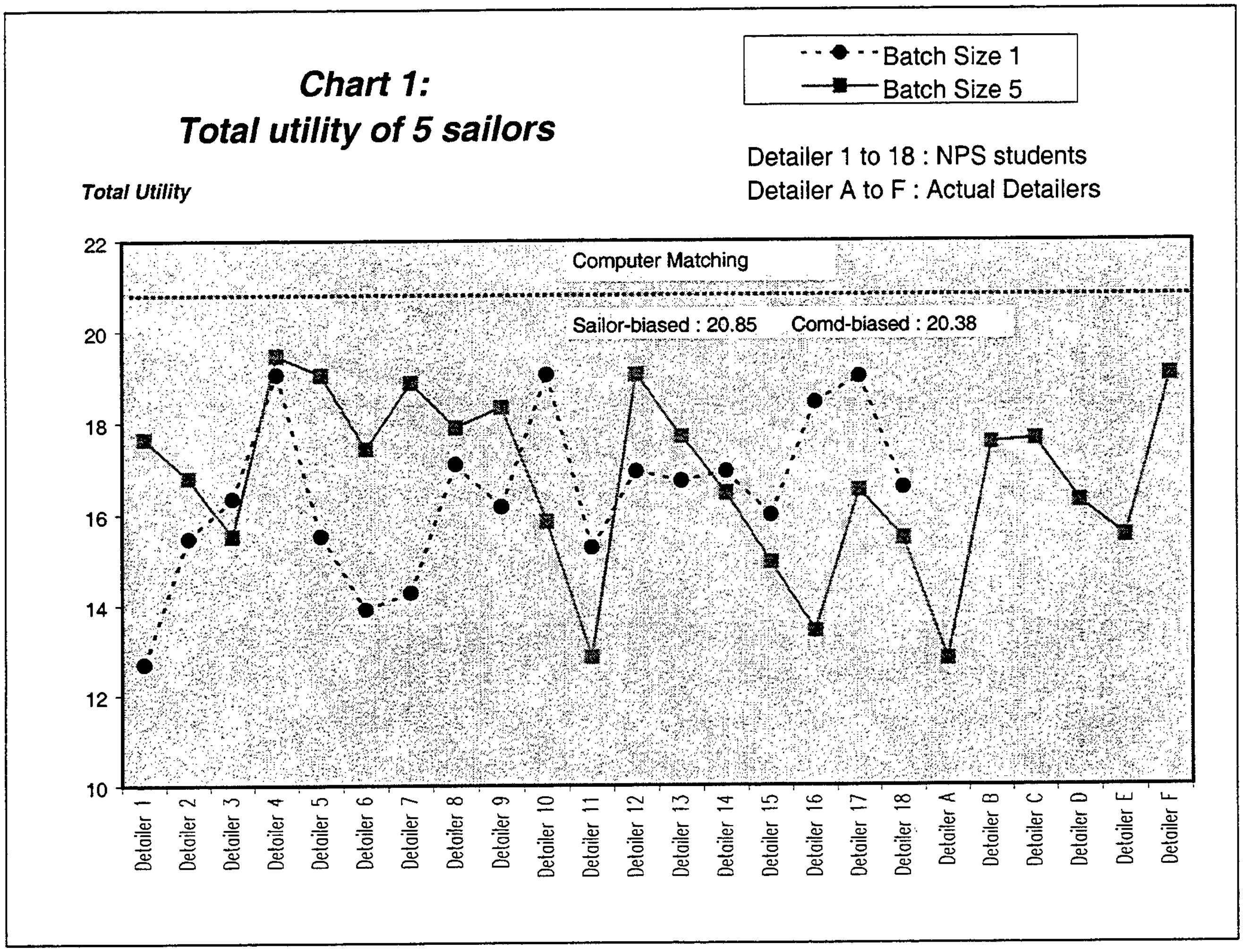
Maximum Sailor Utility by Detailer: 19.05
Minimum Sailor Utility by Detailer: 12.80
Average Sailor Utility by Detailer: 16.48
Standard Deviation: 2.172

Sailor Utility derived from 2-Sided Matching:
20.38 (Command-biased)
20.85 (Sailor-biased)
20.62 (Average)

Average Percentage improvement: 20.05 %[3]

It can be seen that the 2-sided matching results in a higher utility compared to the human detailers. On average, the 2-sided matching results in 20.05 % improvement over that achieved by human detailers. The difference was only significant at 90% confidence level due to the large standard deviation of detailers' results. Interestingly, there is little difference in performance between the NPS students and the actual detailers.

[3] A simple null hypothesis test was conducted to check the statistical significance of the difference between sailors' utility by human detailers and computer matching (using the average utility from Command and Sailor biased Algorithm). Using a confidence level of 95%, the null hypothesis was NOT rejected. The difference in sailors' utility is not significant at this confidence level. If a 90% confidence level was chosen instead, the null hypothesis would have been rejected.



3. Results Of Exercise Three: Matching 10 Sailors To 12 Jobs Using Batch Size Of 1

The detailed results are presented in Appendix C and summarized in chart 2. This exercise was only performed on the first group of 18 officers from NPS.

Maximum Sailor Utility by Detailer: 33.91
Minimum Sailor Utility by Detailer: 25.66
Average Sailor Utility by Detailer: 29.55
Standard Deviation: 2.277

Sailor Utility derived from 2-Sided Matching:
36.79 (Command and Sailor-biased)

Average Percentage Improvement: 19.66%[4]

It can be seen that the 2-sided matching results in a higher utility compared to the human detailers. On average, the 2-sided matching results in 19.66% improvement over that achieved by human detailers. Again, there is tremendous variability across the human detailers.

4. Results Of Exercise Four: Matching 10 Sailors To 12 Jobs Using Batch Size Of 10

(1) First group of 18 officers from NPS

Maximum Sailor Utility by Detailer: 34.04
Minimum Sailor Utility by Detailer: 25.05
Average Sailor Utility by Detailer: 30.07
Standard Deviation: 2.412

Sailor Utility derived from 2-Sided Matching:
36.79 (Command and Sailor-biased)

Average Percentage Improvement: 18.27 %[5]

It can be seen that the 2-sided matching results in a higher utility compared to the human detailers. On average, the 2-sided matching results in 18.27% improvement over that achieved by human detailers. The results for batch size 10 still show tremendous variability across human detailers and only a slight improvement with a batch size of ten vice first come, first served.

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[4] A simple null hypothesis test was conducted to check the statistical significance of the difference between sailors' utility by human detailers and computer matching (using the average utility from Command and Sailor biased Algorithm). Using a confidence level of 99%, the null hypothesis was rejected. The difference in sailors' utility is significant.

[5] A simple null hypothesis test was conducted to check the statistical significance of the difference between sailors' utility by human detailers and computer matching (using the average utility from Command and Sailor biased Algorithm). Using a confidence level of 99%, the null hypothesis was rejected. The difference in sailors' utility is significant.

(2) Second group of 6 detailers from Millington

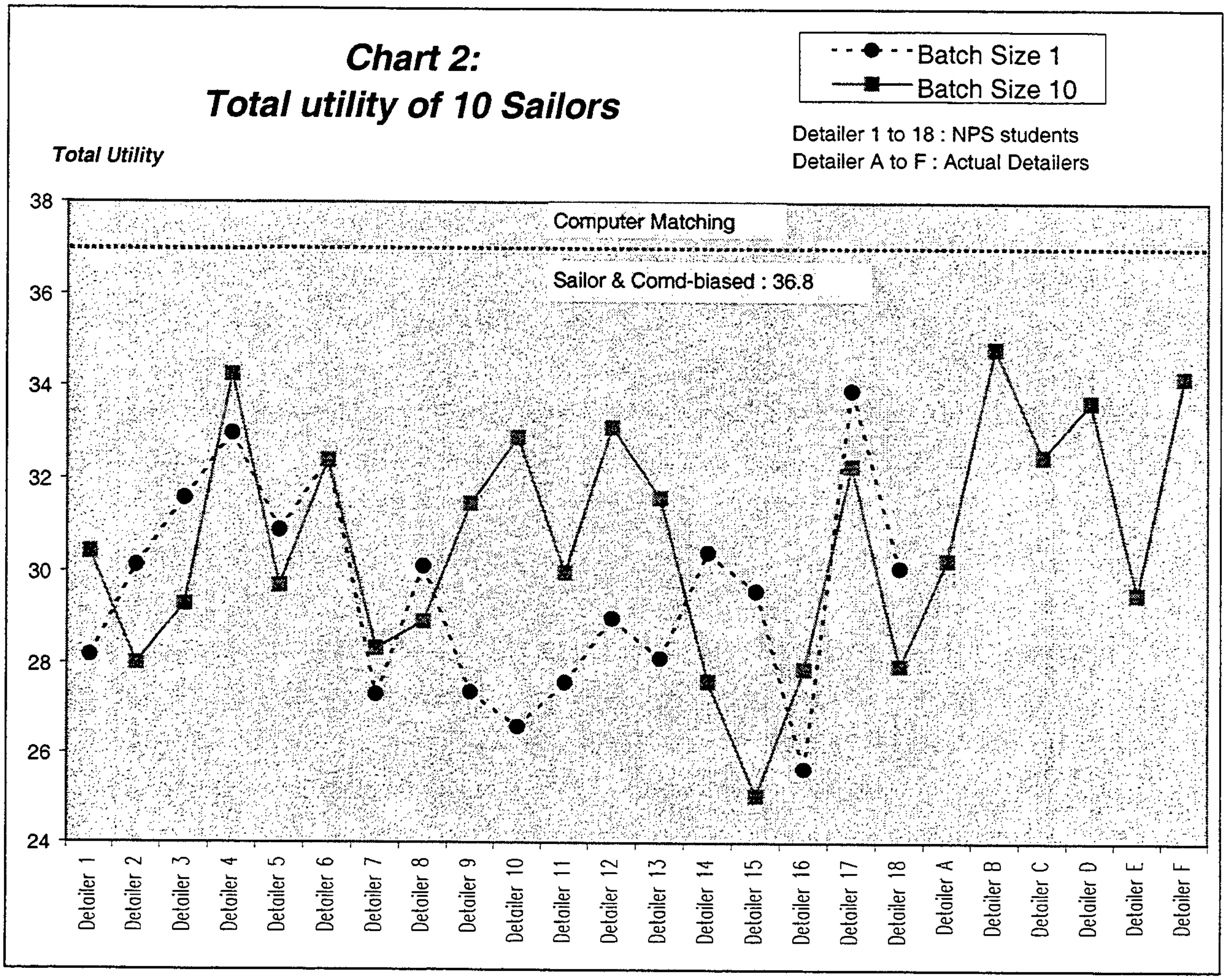
Maximum Sailor Utility by Detailer: 34.81
Minimum Sailor Utility by Detailer: 29.54
Average Sailor Utility by Detailer: 32.49
Standard Deviation: 2.161

Sailor Utility derived from 2-Sided Matching:
36.79 (Command and Sailor-biased)

Average Percentage Improvement: 11.67 %[6]

It can be seen that the 2-sided matching results in a higher utility compared to the human detailers. On average, the 2-sided matching results in 11.67 % improvement over that achieved by human detailers. In this case, there was a more pronounced improvement between the actual detailers and NPS students. Further research is necessary to determine if detailers' performance continues to improve relative to students' performance as the detailing experiment becomes more complex.

[6] A simple null hypothesis test was conducted to check the statistical significance of the difference between sailors' utility by human detailers and computer matching (using the average utility from Command and Sailor biased Algorithm). Using a confidence level of 95%, the null hypothesis was rejected. The difference in sailors' utility is significant.



D. ANALYSIS OF FINDINGS

The following table shows the summary of findings that were conducted from the various economics experiments.

1. 2-Sided Matching Algorithm And Detailers

	Min Sailor Utility	Average Sailor Utility	Max Sailor Utility	2-sided matching algorithm	Average Percentage Improvement
Ex #1 (Batch size=1)	12.7	16.41	19.05	20.38 – 20.85	20.38
Ex #2 (Batch size=5)	12.85 (12.80)*	16.85 (16.48)*	19.47 (19.05)*	20.38 – 20.85	18.26 (20.05)*

	Min Sailor Utility	Average Sailor Utility	Max Sailor Utility	2-sided matching algorithm	Average Percentage Improvement
Ex #3 (Batch size=1)	25.66	29.55	33.91	36.79	19.66
Ex #4 (Batch size=10)	25.05 (29.54)*	30.07 (32.49)*	34.04 (34.81)*	36.79	18.27 (11.67)*

Table 1: Summary of Findings
*Figures in parenthesis denote results from detailers in Millington

The figures indicate that the 2-sided matching algorithm produces a higher sailor utility every time. Even the "best" human detailer in each of the 4 exercises generates a utility that is lower than that from the 2-sided matching algorithm. The 2-sided matching algorithm is able to generate between 18-20% improvement in utility over that of the average human detailer. The difference is significant using at least 90% confidence level.

2. NPS Students And Actual Detailers From Millington

There is also a distinct difference between the results obtained by the 2 separate groups. The NPS group did better in Ex #2 while the detailer group did better in Ex #4. The only difference between the 2 exercises was the magnitude of sailors/billets involved (complexity). Ex #4 involved more sailors (10) and more jobs (12) while Ex #2 involved fewer sailors (5) and fewer jobs (8). A possible explanation could be that the detailers in Millington are used to dealing with a larger number of sailors and matching them to a large pool of available jobs, as part of their job. Hence they are better "conditioned" to handle sailors and jobs on a larger scale than the average NPS officers. This may help explain the fact that the average increase in sailor utility for Ex #4 for the detailers using the 2 sided matching algorithm is only 11% compared to the average 18-20% improvement in the other exercises.

3. Batch Size

Increasing the batch size also helps to improve the level of utility. Comparing the figures between Ex #1 and Ex #2, it is noted that the utility figures are higher in Ex #2 compared to Ex #1. Likewise, the utility figures are higher in Ex #4 compared to Ex #3. This is true at the aggregate level as a larger batch size results in higher utility. However, in examining the results in detail, it is seen that 8 detailers (out of 18) had lower sailor utility in the scenario with a larger batch size. Likewise for Ex #3 and Ex #4, 8 detailers (out of 18) had lower sailor utility in the scenario with a larger batch size. In particular, the minimum utility is lower as batch size increases from 1 to 10, in the case of Ex #3 and Ex #4. The minimum utility in this scenario drops by 2.41% as batch size is increased from 1 to 10.

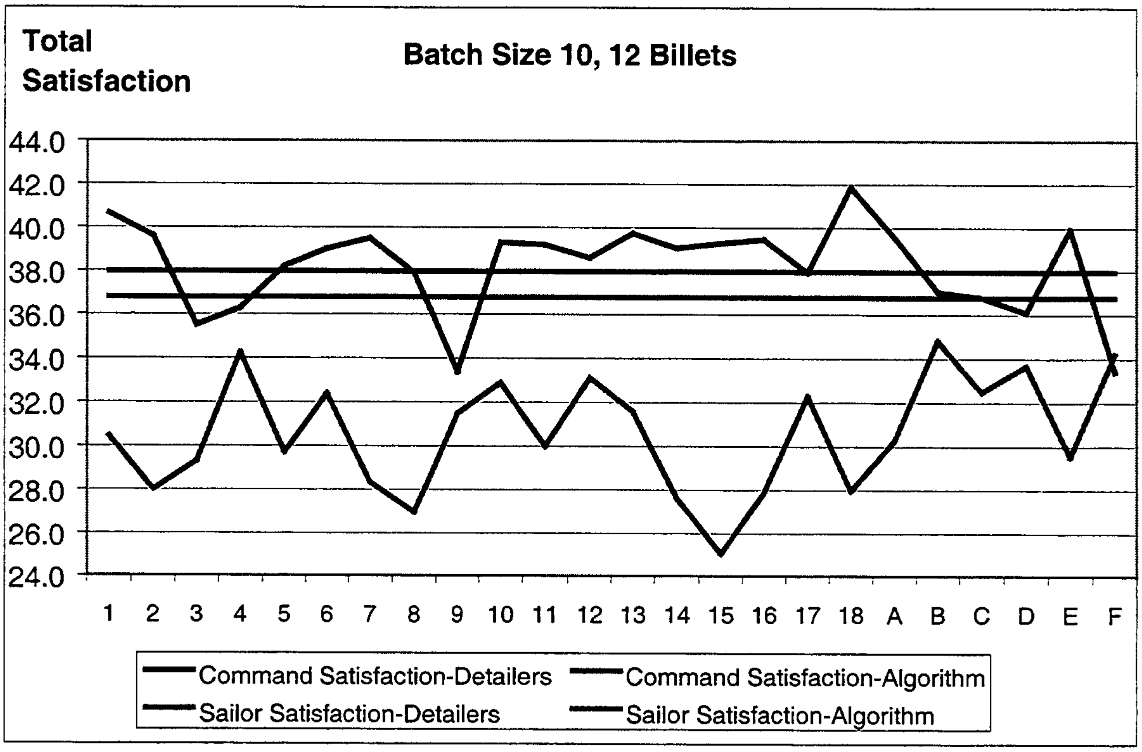
	Min	% Increase	Average	% Increase	Max	% Increase
Ex #1 (Batch size =1)	12.7	1.21 %	16.41	2.15 %	19.05	2.59 %
Ex #2 (Batch size = 5)	12.85		16.85		19.47	
Ex #3 (Batch size =1)	25.66	-2.41 %	29.55	0.99 %	33.91	1.71 %
Ex #4 (Batch size =10)	25.05		30.07		34.04	

Table 2: Comparing the effects of increasing batch size

A possible explanation for some sailors being worse off could be that some detailers may make less than ideal detailing decisions when presented with more candidates. This could reflect some form of information overload, resulting in lower overall utility as compared to a smaller batch size. However, looking at the aggregate level of all detailers, the overall utility level increases as batch size increases. This is one huge advantage that an automated 2-sided matching algorithm has over that of human detailers. Human detailers have a limited capacity to cope with conflicting information. Though the average utility is higher for a larger batch size, some individual sailors may suffer because some human detailers make less than ideal detailing decisions. On the whole, all sailors are better off; however at the individual level, some sailors will be worse off.

At the aggregate level, a larger batch size produces a higher utility. With a larger batch size, more flexibility is introduced into the system. Detailers now have more latitude to assign more available sailors to vacant jobs. Detailers can consider the sailors' preferences to a higher degree of accuracy and better match sailors to vacant jobs. However, when a simple null hypothesis test was conducted to check the statistical significance of the difference in utility derived from different batch sizes, the null hypothesis was not rejected. The difference in utility is therefore not significant.

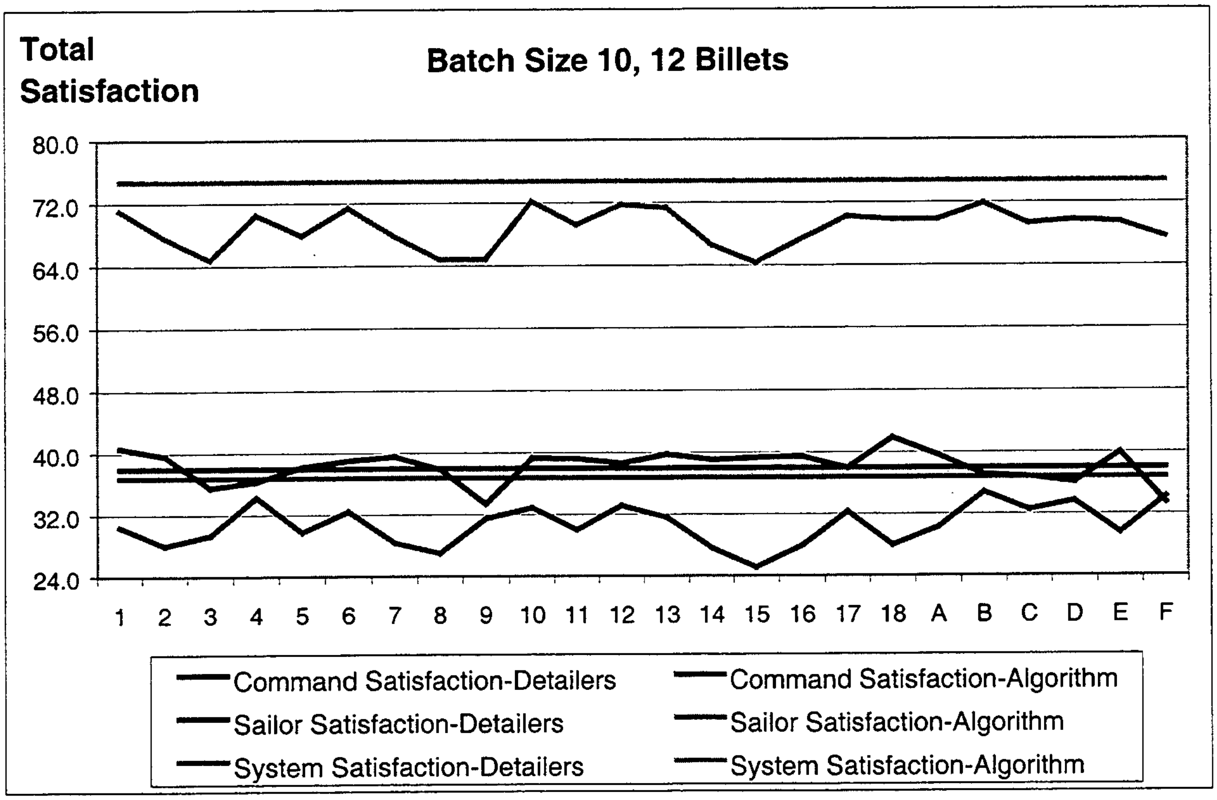
4. Total Command And Sailor Satisfaction



Graph 1: Comparing Command and Sailor Satisfaction between Detailers and 2-sided matching algorithm

In the above graph, the command satisfaction achieved from the detailers is consistently much higher than the sailor satisfaction achieved from the detailers. In many instances, detailers perform much better than the 2-sided matching algorithm with regards to maximizing command satisfaction. This indicates that the detailers place more emphasis on the commands' preferences relative to the sailors' preferences when assigning sailors to commands. This may be beneficial for the commands but this may over-penalize the sailors as sailor satisfaction suffers.

On the other hand, the 2-sided matching algorithm produces a more balanced outcome, with the commands' satisfaction only at a slightly higher level than the sailors' satisfaction. In this outcome, even though commands' satisfaction level is greater than sailors' satisfaction, the difference is only marginal.



Graph 2: Comparing total satisfaction between detailers and the matching algorithm

The graph above shows the total satisfaction from both commands and sailors as a system. The strength of the 2-sided matching algorithm is clearly demonstrated as the total satisfaction achieved from the matching algorithm is higher than that achieved from the detailers. This ensures equity as both commands' and sailors' preferences are being considered and the matching algorithm seeks to consider total satisfaction. This eliminates the possibility of sub-optimization, where sailors' preferences have to give way to commands' preferences or vice versa.

E. CONCLUSIONS

These experiments serve to demonstrate the strengths of an automated 2-sided matching algorithm over the manual human detailing process. A higher average utility is achieved using the 2-sided matching. This is the case regardless of the batch size of the job applicants. An increase of 18-20% in sailor utility is achieved using the 2-sided matching process.

The effects of increasing the batch size of job applicants is however mixed. The average utility figures show a slight increase, between 1 to 2 %. The minimum utility figures show a stark contrast, between -2.4 and 1.2 %. This implies that some detailers do a better job with a smaller batch size (utility decreases as batch size increases) as indicated by these data. The maximum utility shows a slight increase, between 1.71 to 2.59 %. These mixed effects could be caused by information overload and added complexities as detailers try to mentally juggle the sailors' preferences within the large batch and match them to available jobs.

The 2-sided matching algorithm also considers total satisfaction as a system and it gives a higher total satisfaction for both sailors and commands. This is clearly better than the results achieved from the human detailers where total satisfaction achieved as a system is lower; in many instances, sailors' preferences gave way to commands' preferences.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The simple economics experiments demonstrate the superiority that a 2-sided matching algorithm has over that of manual detailing. Adopting the 2-sided matching process produces an overall higher utility on every count. On average, this yields 18-20% improvement in sailor utility compared to the manual detailing system. The advantages are even more evident with a larger batch size. Human beings have a limited capacity to handle and process information; hence, when faced with detailing a large number of sailors to a large number of jobs, the resultant job match may be less than ideal.

On the other hand, an automated 2-sided matching process is better able to cope with the complexities and the increased information requirements than a human detailer. Subsequently more attributes can be added to fine-tune the preferences from both sailors and commands. This will lead to higher satisfaction and higher utility.

In addition, the 2-sided matching algorithm is able to generate a higher total satisfaction as a system (for both sailors and commands). This reduces the possibility of sub-optimization where sailors' preferences have to give way to commands' preferences or vice versa. When the total satisfaction as a system is considered as a whole, greater efficiency and effectiveness is thus achieved.

B. RECOMMENDATIONS FOR DOD

With a 2-sided matching process in place, a better job match will result. This will help to improve the level of satisfaction for both sailors and commands. With more satisfied sailors and commands, the working climate improves and ultimately this will translate into better retention figures for the DoD.

This automated 2-sided matching process also eliminates the subjectivities that are currently present in the detailing process. This ensures equity and fairness across board.

C. SUGGESTED FURTHER STUDIES

This crude experimental model is only the beginning of a long process towards implementing a 2-sided matching algorithm in the DoD. The sample sizes used in this study are very small. Hence, the conclusions need to be further validated. More experiments need to be conducted, with larger sample sizes to make the results and findings more robust.

In addition, these experiments could be conducted on more detailers to examine the difference in behavior between actual detailers and others.

APPENDIX A. SAILORS AND COMMAND PROFILES

	Characteristics of Sailor					Ranking of Preference	
Sailor ID	Current Location	Preferred Location	NEC	Paygrade	Performance	Location	Promotion
1	LANT ConUS	1	2	E5	2	0.1374	0.8626
2	LANT non-ConUS	1	3	E5	3	0.0324	0.9676
3	LANT non-ConUS	1	4	E5	1	0.6768	0.3232
4	PAC non-ConUS	4	4	E4	2	0.4489	0.5511
5	PAC non-ConUS	4	1	E4	3	0.0683	0.9317
6	LANT ConUS	2	1	E6	4	0.0577	0.9423
7	LANT non-ConUS	3	1	E4	4	0.7565	0.2435
8	PAC ConUS	1	1	E5	1	0.4242	0.5758
9	PAC ConUS	1	4	E4	1	0.2154	0.7846
10	PAC ConUS	1	3	E5	4	0.3368	0.6632

	Characteristics of Sailor					Ranking of Preference	
Sailor ID	Current Location	Preferred Location	NEC	Paygrade	Performance	High	Low
1	LANT ConUS	1	2	E5	2	Promotion	Location
2	LANT non-ConUS	1	3	E5	3	Promotion	Location
3	LANT non-ConUS	1	4	E5	1	Location	Promotion
4	PAC non-ConUS	4	4	E4	2	Promotion	Location
5	PAC non-ConUS	4	1	E4	3	Promotion	Location
6	LANT ConUS	2	1	E6	4	Promotion	Location
7	LANT non-ConUS	3	1	E4	4	Location	Promotion
8	PAC ConUS	1	1	E5	1	Promotion	Location
9	PAC ConUS	1	4	E4	1	Promotion	Location
10	PAC ConUS	1	3	E5	4	Promotion	Location

		Characteristics of Job			Ranking of Preference	
Comd Job ID	NEC	Paygrade	Promotability	Location	Training	Performance
1	2	E6	2	4	0.3983	0.6017
2	1	E5	3	1	0.1056	0.8944
3	1	E4	4	3	0.4518	0.5482
4	1	E6	4	3	0.9455	0.0545
5	3	E6	3	1	0.1893	0.8107
6	4	E6	5	4	0.6952	0.3048
7	3	E4	2	1	0.6386	0.3614
8	2	E5	4	4	0.8745	0.1255
9	1	E4	1	1	0.7179	0.2821
10	3	E4	4	1	0.5214	0.4786
11	3	E6	3	4	0.2647	0.7353
12	4	E4	1	4	0.5108	0.4892

		Characteristics of Job			Ranking of Preference	
Comd Job ID	NEC	Paygrade	Promotability	Location	High	Low
1	2	E6	2	4	Performance	Training
2	1	E5	3	1	Performance	Training
3	1	E4	4	3	Performance	Training
4	1	E6	4	3	Training	Performance
5	3	E6	3	1	Performance	Training
6	4	E6	5	4	Training	Performance
7	3	E4	2	1	Training	Performance
8	2	E5	4	4	Training	Performance
9	1	E4	1	1	Training	Performance
10	3	E4	4	1	Training	Performance
11	3	E6	3	4	Performance	Training
12	4	E4	1	4	Training	Performance

Sailor Preference Table

	Sailor #1	Sailor #2	Sailor #3	Sailor #4	Sailor #5	Sailor #6	Sailor #7	Sailor #8	Sailor #9	Sailor #10
1st Preference	10	6	10	6	6	6	3	10	10	10
2nd Preference	6	10	2	8	8	3	4	2	6	2
3rd Preference	3	3	5	11	3	4	6	5	3	5
4th Preference	4	4	7	3	4	10	8	3	4	3
5th Preference	8	8	9	4	10	8	11	4	2	4
6th Preference	2	2	3	1	11	2	1	7	5	6
7th Preference	5	5	4	10	2	5	10	6	8	7
8th Preference	11	11	6	12	5	11	12	8	7	8
9th Preference	7	7	8	2	1	7	2	9	11	11
10th Preference	1	1	11	5	7	1	5	11	1	9
11th Preference	9	9	1	7	12	9	7	1	9	1
12th Preference	12	12	12	9	9	12	9	12	12	12

Command Preference Table

	Comd #1	Comd #2	Comd #3	Comd #4	Comd #5	Comd #6	Comd #7	Comd #8	Comd #9	Comd #10	Comd #11	Comd #12
1st Preference	10	6	6	6	10	10	10	10	6	10	10	10
2nd Preference	6	7	7	7	6	4	2	2	7	2	6	2
3rd Preference	7	10	10	10	7	2	4	1	10	4	7	4
4th Preference	2	2	2	2	2	3	1	4	2	6	2	3
5th Preference	5	5	5	5	5	9	6	3	5	7	5	9
6th Preference	1	1	1	1	4	1	7	9	1	1	4	1
7th Preference	4	4	4	4	1	6	3	6	4	5	1	6
8th Preference	3	3	3	3	3	7	9	7	3	3	3	7
9th Preference	9	8	8	8	9	5	5	5	8	9	9	5
10th Preference	8	9	9	9	8	8	8	8	9	8	8	8

Utility of Sailor to Each Command

	Sailor #1	Sailor #2	Sailor #3	Sailor #4	Sailor #5	Sailor #6	Sailor #7	Sailor #8	Sailor #9	Sailor #10
Comd #1	1.8183	1.9556	1.2511	3.0176	2.1292	2.0000	2.7179	1.4905	1.7226	1.5836
Comd #2	3.2181	3.0501	4.2390	1.8321	2.7831	3.0000	2.2076	3.7259	3.3489	3.5632
Comd #3	3.6367	3.9112	2.5022	3.5154	3.9222	3.9342	4.7355	2.9809	3.4453	3.1671
Comd #4	3.6367	3.9112	2.5022	3.5154	3.9222	3.9342	4.7355	2.9809	3.4453	3.1671
Comd #5	3.2181	3.0501	4.2390	1.8321	2.7831	3.0000	2.2076	3.7259	3.3489	3.5632
Comd #6	4.0082	4.7459	1.6824	5.0000	5.0000	4.7427	3.3974	2.5261	3.5353	2.9076
Comd #7	2.2683	2.0603	3.7183	1.4652	1.9075	2.0473	2.0000	2.9502	2.4364	2.7231
Comd #8	3.3063	3.8243	1.5653	4.4214	4.0614	3.8433	3.2177	2.2215	2.9675	2.5077
Comd #9	1.2475	1.0535	2.9720	1.0000	1.0000	1.0654	1.6894	1.9794	1.4143	1.7196
Comd #10	4.1245	4.0290	4.6521	2.1468	3.6386	3.9342	2.3678	4.3972	4.1969	4.3122
Comd #11	2.5797	2.8951	1.4263	3.7732	3.1065	2.9307	3.0000	1.8824	2.3679	2.0721
Comd #12	1.0000	1.0000	1.0000	2.0595	1.1162	1.0408	2.2958	1.0000	1.0000	1.0000

Utility of Command to Each Sailor

	Comd #1	Comd #2	Comd #3	Comd #4	Comd #5	Comd #6	Comd #7	Comd #8	Comd #9	Comd #10	Comd #11	Comd #12
Sailor #1	3.2949	2.6899	3.4193	4.8147	2.6995	2.5000	3.2389	4.5834	4.1119	3.0885	2.7832	2.5000
Sailor #2	4.2053	3.8657	4.2704	4.9223	3.9599	3.7500	4.5063	4.8227	4.6102	4.3568	4.0467	3.7500
Sailor #3	2.1713	1.4471	2.3383	4.6363	1.6252	3.2768	3.0296	4.2016	3.3816	2.5751	1.8041	2.5377
Sailor #4	3.2949	2.6899	3.4193	4.8147	2.8506	4.0477	3.8920	4.5834	4.1119	3.5882	3.0035	3.5621
Sailor #5	3.7500	3.8657	4.2704	4.9223	3.4729	1.7472	2.8945	3.7500	4.6102	3.0355	3.3684	2.1396
Sailor #6	4.4587	5.0000	5.0000	5.0000	4.3850	1.9073	3.2117	3.8879	5.0000	3.4836	4.1619	2.4629
Sailor #7	4.4587	5.0000	5.0000	5.0000	4.3850	1.9073	3.2117	3.8879	5.0000	3.4836	4.1619	2.4629
Sailor #8	1.9362	1.4471	2.3383	4.6363	1.4253	1.2500	1.9460	3.2670	3.3816	1.7941	1.5017	1.2500
Sailor #9	2.1713	1.4471	2.3383	4.6363	1.6252	3.2768	3.0296	4.2016	3.3816	2.5751	1.8041	2.5377
Sailor #10	5.0000	5.0000	5.0000	5.0000	5.0000	4.0937	5.0000	5.0000	5.0000	5.0000	5.0000	4.3167

APPENDIX B. DETAILED EXPERIMENTAL INSTRUCTIONS

EXPERIMENTAL INSTRUCTIONS

Navy Personnel Detailing Task

Suan Jow Tan and Chee Meng Yeong

Please wait for instructions.

____

Print your name

General

You are acting as an enlisted personnel detailing specialist assigned to match a small group of sailors with jobs at several naval commands that need to be filled immediately. The Navy has a policy of first filling the needs of naval commands even though the specific job preferences of sailors are important. Also, you must make assignments on a first-come-first-served basis; that is, assign the sailors in the order of the batch in which they arrive. In this exercise, sailors are rotating from a sea job to a shore job and they are all in the range of paygrades from E4 to E6.

Instructions

There are 2 lists of jobs at several naval commands that need to be filled immediately from 2 separate pools of sailors. One list has 8 jobs to be filled from a pool of 5 sailors and the other list has 12 jobs to be filled from a pool of 10 sailors. The job lists and sailor pools have been randomly selected from a database including 2000 jobs and sailors. Consider sailors' preferences to the maximum extent practical without jeopardizing the needs of the naval commands.

For each list of jobs vacancies, the assignment of sailors to jobs will be done in different batch sizes. For the first list of 8 vacancies, the batch sizes will be 1 and 5, and for the second list of 12 vacancies, the batch sizes will be 1 and 10. For the batch size of 1 sailor, the information about each sailor will be flashed on the screen in sequence, and detailers assign sailors to jobs one at a time. For the larger batch size of 5 and 10 sailors, the information about sailors to be detailed will be given out on paper to the detailers in batches. Each batch of sailors has to be assigned a job before information about the next batch of sailors is given out. There will be 2 matching exercises for the list of 8 job vacancies and another 2 matching exercises for the list of 12 job vacancies, making a total of 4 job matching exercises. A new form will be used for each job matching exercise.

Please place your name on each form and turn it in when instructed to do so.

Jobs to be Filled

Different skill sets and experiences are required to perform the wide variety of jobs. Some commands place greater premium on the level of NEC training and experience, while others may prefer sailors having a certain level of performance. They will rank their preference on the level of NEC of training and performance as high or low. The table below shows the other attributes that are also considered by the various commands and a description of the characteristics of the different jobs.

Promotion Prospect:	Location:	Paygrade:	NEC Training Level:
1: Low 2: Moderate 3: Average 4: High 5: Excellent	LANT CONUS LANT NON-CONUS PAC CONUS PAC NON-CONUS	1:E4 2:E5 3:E6	1: No NEC 2: General NEC 3: Equipment Operations NEC 4: Equipment Maintenance NEC

Explanatory Notes:

a. Paygrade indicates the paygrade level (ranging from E4 to E6) that is pegged to the job.

b. NEC Level refers to the Command preferred level of training and experience the incumbent possess before assuming the job.

c. Promotion prospect indicates the likelihood of being promoted while on job or at the end of the tour.

d. Location indicates the geographical location of the job posting.

Sailors and Preferences

Similarly, sailors will have their own preferences over certain jobs that are available. They will also rank their preference to maximize their own utility. They will rank their preference for choice of location for the next job and the job's promotion prospects. These preferences are expressed as high or low. The table below lists the attributes of the sailor that are crucial to the job-matching exercises.

Current Area:	NEC Level:	Paygrade:	Preferred Location:	Performance:
LANT CONUS LANT NON-CONUS PAC CONUS PAC NON-CONUS	1: No NEC 2: General NEC 3: Equipment Operations NEC 4: Equipment Maintenance NEC	1:E4 2:E5 3:E6	LANT CONUS LANT NON-CONUS PAC CONUS PAC NON-CONUS	1: Not Promote 2: Promote 3: Must promote 4: Early Promote

Explanatory Notes:

a. Paygrade refers to the current level of the sailor, ranging from E4 to E6.

b. NEC Level refers to the level of training the sailor has received.

c. Performance refers to the likelihood of the sailor being promoted, an indication of his performance on the job.

d. Current area refers to the geographical location of the sailor.

e. Preferred location refers to the desired geographical location of the sailor for his next job.

Specific Order of Sailor Assignments

Each job-matching exercise needs to be completed on a batch basis. This is to simulate the process that detailers go through as they job-match sailors to vacancies as and when the job openings arise and sailors become available. There are a total of 3 batch sizes for each of the two job-matching scenarios, making a total of 6 job-matching exercises.

Job-Matching Scenario #1 (5 sailors, 8 jobs)

a. Batch size = 1 (available sailors turn up 1 at a time)

b. Batch size = 5 (available sailors turn up 5 at a time)

Job-Matching Scenario #2 (10 sailors, 12 jobs)

a. Batch size = 1 (available sailors turn up 1 at a time)

b. Batch size = 10 (available sailors turn up 10 at a time)

QUESTIONNAIRE (TO BE FILLED IN AT THE END OF THE DETAILING EXERCISE)

1. During this detailing exercise, what factors were considered most pertinent in your assignment?

____

____

____

____

____

____

2. What is the ranking order of the factors that you used? (i.e. which factor did you look at first, followed by which other factor, and so on)

____

____

____

____

____

3. What factors were not considered at all? Why not?

____

____

____

4. How can this detailing simulation exercise be further improved upon?

____

____

____

____

APPENDIX C. DETAILED EXPERIMENTAL RESULTS

Exercise 1: Batch Size #1 for 8 jobs

						Utility					
	Sailor 1	**Sailor 2**	**Sailor 3**	**Sailor 4**	**Sailor 5**	**Sailor 1**	**Sailor 2**	**Sailor 3**	**Sailor 4**	**Sailor 5**	***Sum of Utility***
Detailer 1	8	7	6	3	1	3.3063	2.0603	1.6824	3.5154	2.1292	12.6936
Detailer 2	8	5	6	3	4	3.3063	3.0501	1.6824	3.5154	3.9222	15.4763
Detailer 3	2	5	8	3	6	3.2181	3.0501	1.5653	3.5154	5.0000	16.3489
Detailer 4	5	2	7	6	8	3.2181	3.0501	3.7183	5.0000	4.0614	19.0480
Detailer 5	5	2	6	3	8	3.2181	3.0501	1.6824	3.5154	4.0614	15.5274
Detailer 6	1	7	6	8	3	1.8183	2.0603	1.6824	4.4214	3.9222	13.9046
Detailer 7	2	7	8	3	4	3.2181	2.0603	1.5653	3.5154	3.9222	14.2812
Detailer 8	2	7	5	3	8	3.2181	2.0603	4.2390	3.5154	4.0614	17.0942
Detailer 9	1	5	7	3	8	1.8183	3.0501	3.7183	3.5154	4.0614	16.1636
Detailer 10	2	5	7	6	8	3.2181	3.0501	3.7183	5.0000	4.0614	19.0480
Detailer 11	2	5	8	4	3	3.2181	3.0501	1.5653	3.5154	3.9222	15.2710
Detailer 12	1	5	7	8	3	1.8183	3.0501	3.7183	4.4214	3.9222	16.9304
Detailer 13	2	4	1	8	3	3.2181	3.9112	1.2511	4.4214	3.9222	16.7240
Detailer 14	1	5	7	8	3	1.8183	3.0501	3.7183	4.4214	3.9222	16.9304
Detailer 15	8	5	2	7	3	3.3063	3.0501	4.2390	1.4652	3.9222	15.9828
Detailer 16	2	7	5	6	3	3.2181	2.0603	4.2390	5.0000	3.9222	18.4396
Detailer 17	8	2	7	6	3	3.3063	3.0501	3.7183	5.0000	3.9222	18.9969
Detailer 18	2	5	1	6	8	3.2181	3.0501	1.2511	5.0000	4.0614	16.5807
										Total:	*295.4413*
										Average:	*16.4134*

Exercise 2: Batch Size #5 for 8 jobs

	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Utility Sailor 1	Utility Sailor 2	Utility Sailor 3	Utility Sailor 4	Utility Sailor 5		Sum of Utility
Detailer 1	1	5	7	6	8	1.8183	3.0501	3.7183	5.0000	4.0614		17.6482
Detailer 2	8	7	4	6	3	3.3063	2.0603	2.5022	5.0000	3.9222		16.7910
Detailer 3	2	5	6	3	8	3.2181	3.0501	1.6824	3.5154	4.0614		15.5274
Detailer 4	4	5	7	6	8	3.6367	3.0501	3.7183	5.0000	4.0614		19.4665
Detailer 5	2	5	7	6	8	3.2181	3.0501	3.7183	5.0000	4.0614		19.0480
Detailer 6	2	5	7	4	3	3.2181	3.0501	3.7183	3.5154	3.9222		17.4241
Detailer 7	6	2	5	3	8	4.0082	3.0501	4.2390	3.5154	4.0614		18.8741
Detailer 8	7	5	2	8	3	2.2683	3.0501	4.2390	4.4214	3.9222		17.9010
Detailer 9	2	5	7	8	3	3.2181	3.0501	3.7183	4.4214	3.9222		18.3301
Detailer 10	2	5	3	1	8	3.2181	3.0501	2.5022	3.0176	4.0614		15.8495
Detailer 11	1	5	6	3	2	1.8183	3.0501	1.6824	3.5154	2.7831		12.8493
Detailer 12	2	5	7	6	8	3.2181	3.0501	3.7183	5.0000	4.0614		19.0480
Detailer 13	2	8	7	1	3	3.2181	3.8243	3.7183	3.0176	3.9222		17.7005
Detailer 14	2	7	5	1	3	3.2181	2.0603	4.2390	3.0176	3.9222		16.4572
Detailer 15	1	5	4	3	8	1.8183	3.0501	2.5022	3.5154	4.0614		14.9475
Detailer 16	8	5	6	7	3	3.3063	3.0501	1.6824	1.4652	3.9222		13.4261
Detailer 17	8	5	1	6	3	3.3063	3.0501	1.2511	5.0000	3.9222		16.5297
Detailer 18	8	5	6	4	3	3.3063	3.0501	1.6824	3.5154	3.9222		15.4763
Detailer A	8	7	6	2	3	3.3063	2.0603	1.6824	1.8321	3.9222		12.8032
Detailer B	2	5	7	3	8	3.2181	3.0501	3.7183	3.5154	4.0614		17.5633
Detailer C	1	5	7	6	8	1.8183	3.0501	3.7183	5.0000	4.0614		17.6482
Detailer D	2	5	6	8	4	3.2181	3.0501	1.6824	4.4214	3.9222		16.2941
Detailer E	2	5	6	3	8	3.2181	3.0501	1.6824	3.5154	4.0614		15.5274
Detailer F	2	5	7	6	8	3.2181	3.0501	3.7183	5.0000	4.0614		19.0480
Sailor bias	4	3	2	6	8	3.6367	3.9112	4.2390	5.0000	4.0614		***20.8483***
Comd bias	8	3	2	6	4	3.3063	3.9112	4.2390	5.0000	3.9222		***20.3787***
											Total:	*303.2944*
											Average:	*16.8497*

Exercise 3: Batch Size #1 for 12 jobs

	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Sailor 6	Sailor 7	Sailor 8	Sailor 9	Sailor 10
Detailer 1	8	5	12	3	2	4	9	10	7	11
Detailer 2	8	5	12	6	3	4	9	2	7	11
Detailer 3	2	5	12	11	8	6	3	4	7	1
Detailer 4	8	10	12	6	4	2	3	9	7	5
Detailer 5	2	5	12	6	3	9	4	10	7	11
Detailer 6	8	10	12	6	3	2	4	9	5	11
Detailer 7	8	5	12	9	3	11	2	4	10	7
Detailer 8	8	5	2	12	9	1	3	4	7	10
Detailer 9	1	10	12	7	3	2	4	9	5	11
Detailer 10	8	5	12	3	2	1	9	4	10	11
Detailer 11	9	5	12	8	3	4	2	0	0	11
Detailer 12	1	6	12	7	3	4	8	9	2	5
Detailer 13	2	10	12	7	8	5	3	9	1	6
Detailer 14	9	5	2	8	3	1	12	4	10	11
Detailer 15	2	5	9	12	3	4	0	8	0	11
Detailer 16	1	5	12	9	3	11	2	4	7	10
Detailer 17	2	5	12	6	8	3	4	10	7	11
Detailer 18	1	2	10	6	3	4	9	7	12	11
Computer	2	8	5	6	11	3	4	9	7	10

Utility

	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Sailor 6	Sailor 7	Sailor 8	Sailor 9	Sailor 10		Sum	Adjusted
Detailer 1	3.3063	3.0501	1.0000	3.5154	2.7831	3.9342	1.6894	4.3972	2.4364	2.0721		28.1841	28.1841
Detailer 2	3.3063	3.0501	1.0000	5.0000	3.9222	3.9342	1.6894	3.7259	2.4364	2.0721		30.1366	30.1366
Detailer 3	3.2181	3.0501	1.0000	3.7732	4.0614	4.7427	4.7355	2.9809	2.4364	1.5836		31.5819	31.5819
Detailer 4	3.3063	4.0290	1.0000	5.0000	3.9222	3.0000	4.7355	1.9794	2.4364	3.5632		32.9720	32.9720
Detailer 5	3.2181	3.0501	1.0000	5.0000	3.9222	1.0654	4.7355	4.3972	2.4364	2.0721		30.8969	30.8969
Detailer 6	3.3063	4.0290	1.0000	5.0000	3.9222	3.0000	4.7355	1.9794	3.3489	2.0721		32.3935	32.3935
Detailer 7	3.3063	3.0501	1.0000	1.0000	3.9222	2.9307	2.2076	2.9809	4.1969	2.7231		27.3178	27.3178
Detailer 8	3.3063	3.0501	4.2390	2.0595	1.0000	2.0000	4.7355	2.9809	2.4364	4.3122		30.1200	30.1200
Detailer 9	1.8183	4.0290	1.0000	1.4652	3.9222	3.0000	4.7355	1.9794	3.3489	2.0721		27.3707	27.3707
Detailer 10	3.3063	3.0501	1.0000	3.5154	2.7831	2.0000	1.6894	2.9809	4.1969	2.0721		26.5943	26.5943
Detailer 11	1.2475	3.0501	1.0000	4.4214	3.9222	3.9342	2.2076	0.0000	0.0000	2.0721		21.8550	27.5918
Detailer 12	1.8183	4.7459	1.0000	1.4652	3.9222	3.9342	3.2177	1.9794	3.3489	3.5632		28.9950	28.9950
Detailer 13	3.2181	4.0290	1.0000	1.4652	4.0614	3.0000	4.7355	1.9794	1.7226	2.9076		28.1190	28.1190
Detailer 14	1.2475	3.0501	4.2390	4.4214	3.9222	2.0000	2.2958	2.9809	4.1969	2.0721		30.4259	30.4259
Detailer 15	3.2181	3.0501	2.9720	2.0595	3.9222	3.9342	0.0000	2.2215	0.0000	2.0721		23.4497	29.5928
Detailer 16	1.8183	3.0501	1.0000	1.0000	3.9222	2.9307	2.2076	2.9809	2.4364	4.3122		25.6583	25.6583
Detailer 17	3.2181	3.0501	1.0000	5.0000	4.0614	3.9342	4.7355	4.3972	2.4364	2.0721		33.9050	33.9050
Detailer 18	1.8183	3.0501	4.6521	5.0000	3.9222	3.9342	1.6894	2.9502	1.0000	2.0721		30.0885	30.0885
						Average:	3.3399	2.9336	2.8032		***Total:***	*520.0644*	*531.9443*
											Average:	*28.89247*	*29.55246*

Exercise 4: Batch Size #10 for 12 jobs

	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Sailor 6	Sailor 7	Sailor 8	Sailor 9	Sailor 10
Detailer 1	8	5	6	12	4	2	3	7	9	10
Detailer 2	1	5	6	12	2	4	3	8	9	10
Detailer 3	4	2	1	7	10	6	3	8	12	5
Detailer 4	7	10	9	6	11	8	4	2	12	5
Detailer 5	2	5	6	12	1	4	3	9	10	7
Detailer 6	8	10	12	6	3	5	4	9	2	11
Detailer 7	9	7	4	8	12	2	3	1	10	5
Detailer 8	2	5	9	12	3	8	10	4	7	11
Detailer 9	2	4	9	12	3	6	8	1	11	5
Detailer 10	8	11	7	6	9	4	3	2	12	5
Detailer 11	1	5	12	8	2	4	3	9	10	11
Detailer 12	1	11	2	6	9	4	3	7	8	5
Detailer 13	1	11	7	8	2	4	3	9	12	10
Detailer 14	8	5	6	12	1	4	2	3	10	11
Detailer 15	8	5	6	9	2	4	3	1	12	11
Detailer 16	1	11	6	12	2	4	3	9	7	5
Detailer 17	1	5	12	6	8	4	3	7	9	10
Detailer 18	8	5	6	12	3	2	9	4	10	11
Detailer A	8	7	6	12	9	4	3	2	10	5
Detailer B	6	5	2	12	8	11	3	4	7	10
Detailer C	5	2	7	12	8	11	4	3	9	10
Detailer D	2	5	9	12	8	4	3	7	11	10
Detailer E	2	9	6	12	8	5	3	4	7	10
Detailer F	11	2	7	12	8	6	3	1	10	5
Computer	2	8	5	6	11	3	4	9	7	10

Utility

	Sailor 1	Sailor 2	Sailor 3	Sailor 4	Sailor 5	Sailor 6	Sailor 7	Sailor 8	Sailor 9	Sailor 10
Detailer 1	3.3063	3.0501	1.6824	2.0595	3.9222	3.0000	4.7355	2.9502	1.4143	4.3122
Detailer 2	1.8183	3.0501	1.6824	2.0595	2.7831	3.9342	4.7355	2.2215	1.4143	4.3122
Detailer 3	3.6367	3.0501	1.2511	1.4652	3.6386	4.7427	4.7355	2.2215	1.0000	3.5632
Detailer 4	2.2683	4.0290	2.9720	5.0000	3.1065	3.8433	4.7355	3.7259	1.0000	3.5632
Detailer 5	3.2181	3.0501	1.6824	2.0595	2.1292	3.9342	4.7355	1.9794	4.1969	2.7231
Detailer 6	3.3063	4.0290	1.0000	5.0000	3.9222	3.0000	4.7355	1.9794	3.3489	2.0721
Detailer 7	1.2475	2.0603	2.5022	4.4214	1.1162	3.0000	4.7355	1.4905	4.1969	3.5632
Detailer 8	3.2181	3.0501	2.9720	2.0595	3.9222	3.8433	2.3678	2.9809	2.4364	2.0721
Detailer 9	3.2181	3.9112	2.9720	2.0595	3.9222	4.7427	3.2177	1.4905	2.3679	3.5632
Detailer 10	3.3063	2.8951	3.7183	5.0000	1.0000	3.9342	4.7355	3.7259	1.0000	3.5632
Detailer 11	1.8183	3.0501	1.0000	4.4214	2.7831	3.9342	4.7355	1.9794	4.1969	2.0721
Detailer 12	1.8183	2.8951	4.2390	5.0000	1.0000	3.9342	4.7355	2.9502	2.9675	3.5632
Detailer 13	1.8183	2.8951	3.7183	4.4214	2.7831	3.9342	4.7355	1.9794	1.0000	4.3122
Detailer 14	3.3063	3.0501	1.6824	2.0595	2.1292	3.9342	2.2076	2.9809	4.1969	2.0721
Detailer 15	3.3063	3.0501	1.6824	1.0000	2.7831	3.9342	4.7355	1.4905	1.0000	2.0721
Detailer 16	1.8183	2.8951	1.6824	2.0595	2.7831	3.9342	4.7355	1.9794	2.4364	3.5632
Detailer 17	1.8183	3.0501	1.0000	5.0000	4.0614	3.9342	4.7355	2.9502	1.4143	4.3122
Detailer 18	3.3063	3.0501	1.6824	2.0595	3.9222	3.0000	1.6894	2.9809	4.1969	2.0721
Detailer A	3.3063	2.0603	1.6824	2.0595	1.0000	3.9342	4.7355	3.7259	4.1969	3.5632
Detailer B	4.0082	3.0501	4.2390	2.0595	4.0614	2.9307	4.7355	2.9809	2.4364	4.3122
Detailer C	3.2181	3.0501	3.7183	2.0595	4.0614	2.9307	4.7355	2.9809	1.4143	4.3122
Detailer D	3.2181	3.0501	2.9720	2.0595	4.0614	3.9342	4.7355	2.9502	2.3679	4.3122
Detailer E	3.2181	1.0535	1.6824	2.0595	4.0614	3.0000	4.7355	2.9809	2.4364	4.3122
Detailer F	2.5797	3.0501	3.7183	2.0595	4.0614	4.7427	4.7355	1.4905	4.1969	3.5632
Computer	3.2181	3.8243	4.2390	5.0000	3.1065	3.9342	4.7355	1.9794	2.4364	4.3122

COMPARING TOTAL UTILITY AS A SYSTEM (10 SAILORS FOR 12 BILLETS)

Detailer	Command Total Utility Detailers	Command Total Utility Algorithm	Sailor Total Utility Detailers	Sailor Total Utility Algorithm	System Total Utility Detailers	System Total Utility Algorithm	Difference
1	40.6	38.0	30.4	36.8	71.1	74.8	3.7
2	39.6	38.0	28.0	36.8	67.6	74.8	7.1
3	35.5	38.0	29.3	36.8	64.8	74.8	10.0
4	36.3	38.0	34.2	36.8	70.5	74.8	4.2
5	38.2	38.0	29.7	36.8	67.9	74.8	6.8
6	39.0	38.0	32.4	36.8	71.4	74.8	3.3
7	39.5	38.0	28.3	36.8	67.8	74.8	6.9
8	37.9	38.0	27.0	36.8	64.9	74.8	9.9
9	33.4	38.0	31.5	36.8	64.8	74.8	9.9
10	39.3	38.0	32.9	36.8	72.2	74.8	2.6
11	39.2	38.0	30.0	36.8	69.2	74.8	5.6
12	38.6	38.0	33.1	36.8	71.7	74.8	3.1
13	39.7	38.0	31.6	36.8	71.3	74.8	3.4
14	39.0	38.0	27.6	36.8	66.7	74.8	8.1
15	39.3	38.0	25.1	36.8	64.3	74.8	10.4
16	39.5	38.0	27.9	36.8	67.3	74.8	7.4
17	37.9	38.0	32.3	36.8	70.2	74.8	4.6
18	41.9	38.0	28.0	36.8	69.8	74.8	4.9
A	39.6	38.0	30.3	36.8	69.8	74.8	4.9
B	37.0	38.0	34.8	36.8	71.9	74.8	2.9
C	36.8	38.0	32.5	36.8	69.3	74.8	5.5
D	36.1	38.0	33.7	36.8	69.8	74.8	5.0
E	39.9	38.0	29.5	36.8	69.5	74.8	5.3
F	33.4	38.0	34.2	36.8	67.6	74.8	7.1

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