

# MASTER OF SCIENCE IN OPERATIONS RESEARCH

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## **SLEEP PATTERNS IN U.S. NAVY RECRUITS: AN ASSESSMENT OF THE IMPACT OF CHANGING SLEEP REGIMENS**

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**Master of Science in Operations Research-September 2002**

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The U.S. Navy Recruit Training Command in Great Lakes, Illinois is responsible for training all enlisted personnel, about 50,000 young recruits per year. Demands on these recruits are steep and there is concern that by restricting the amount of sleep, learning efficiency is adversely affected. There are additional concerns about possible increases in attrition and reductions in morale due to sleep deprivation. Every minute of the 63 day training schedule is closely managed, including the time allocated for sleep. Within recent years, the designated sleep regimens have changed considerably from 6 hours of sleep (2200 to 0400) in 2001 to 8 hours of sleep (2200 to 0600) as of June 2002. In the months of April through June, 2002, data was collected on the quantity and quality of sleep received by 31 volunteer recruits in two 8 hour conditions: 2100 to 0500 and 2200 to 0600. Using wrist activity monitors, the actual amount of sleep was calculated and contrasted with the expected amount for each participant. Additionally, comparisons were made between bedtimes (2100 vs. 2200), gender, different training divisions, nights with and without sleep disruptions (due to watch standing and other factors), and different days of the week.

**KEYWORDS:** Sleep, Fatigue, Sleep Deprivation, Circadian Rhythm, Sleep Stages, Actigraphy, Navy Recruits, Adolescents, Melatonin

## **ANALYSIS OF OPLAN 5027 DRY CARGO FLOW IN JAPAN (U)**

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(U) The United States Pacific Command (USPACOM) controls United States military forces in the Pacific theater. USPACOM must ensure sufficient storage and distribution assets are available to satisfy its wartime dry cargo (e.g., spare parts, food) requirements in the event of hostilities. The Commander, Logistics Group Western Pacific oversees the flow of dry cargo in Japan for the U.S. Navy and the Combat Logistics Force consisting of oil tankers (T-AO), ammunition ships (T-AE), and Fast Combat Support Ships (T-AFS). Previous analysis lacked the detail to adequately analyze the implications of the Time Phased Force Deployment Data (TPFDD) on dry cargo distribution assets in Japan. This thesis develops an optimization-based decision support system, the Japan Dry Cargo Flow Model (JDCFM), to analyze delivery plans for daily shipments of two dry cargo types via three different transportation modes (trucks, barges, and railcars) amongst eight terminals. Using JDCFM, this thesis identifies possible shortfalls in the dry cargo delivery network in Japan, investigates specific scenarios that might impact the network, and develops a tool that is responsive to changing conditions in the theater.

**KEYWORDS:** Dry Cargo, Distribution, Transportation, Logistics, Linear Programming, Optimization, Operational Planning

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## **AN ANALYSIS OF THE EFFECTS OF ENVIRONMENT AND CAREER LONGEVITY ON THE SLEEP PATTERNS OF ENLISTED U.S. NAVY SUB MARINERS**

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This thesis will examine the reported sleep patterns among a sample of U.S. Navy Submarine Force enlisted personnel, and make an initial assessment of their perception of their sleep allowances at sea and ashore. The goal of this research is to determine if a shift in working environment from shore duty (baseline) to the arduous environment of sea duty (underway) has an effect on the sleep patterns of enlisted submariners. Additionally, any effects of career longevity and “optimal sleep duration (self-reported)” will also be investigated. This thesis will also include a review and discussion of studies in the area of sleep deprivation and cognitive dissonance reduction theory, and will attempt to address the idea that cognitions/attitudes change to accommodate behavior or the external environment, perhaps presenting an explanation for those sleep patterns.

**KEYWORDS:** Fatigue, Submarine, Naps, Sleep Deprivation, Sleep Loss, Sustained Operations, Continuous Operations

## **A COMPARISON OF THE OPERATIONAL POTENTIAL AND CAPABILITY OF TWO COMBAT LOGISTICS FORCE ALTERNATIVES**

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A recent study by the fleet suggests two feasible near-term CLF alternatives (one with 12 T-AKES, 18 T-AOs, and 4 TAOE6s and the other with 9 TAKES, 14 TAOs, 4 TAOE6s and 4 TAOE(X)s) and recommends the latter as more flexible. The goal is to enable decision makers to determine if the latter, more expensive alternative is worth the additional cost. Previous studies have used, among other techniques, steady-state analysis and simulation to analyze the CLF. Descriptive models, such as simulations, do not allow us to determine the full potential of the force, and steady-state analyses can easily miss critical details such as constraints on scheduling that can significantly impact performance.

An optimization model is developed that prescribes a near-optimal schedule for shuttle ship deliveries to battle groups for a dual MTW scenario. Data is adapted from the fleet study for use in our optimization model. This includes the force supported, the areas of operation, capacities and consumption rates of DFM, JP5, dry stores, and ordnance. To account for transit times precisely, a global sea-route model is presented that shows where any shuttle ship would travel to deliver to any battle group. The results suggest how to employ the shuttle ships, including where they should be pre-positioned. These results also allow us to compare various performance measure evaluated for each CLF alternative in an effort to quantify flexibility. In addition, the combatant off-station times resulting from using a T-AOE station ship versus a T-AO and T-AKE acting as a substitute station ship is compared, and for a 26-knot station ship versus a 20-knot station ship.

**KEYWORDS:** T-AKE, T-AOE(X), Optimization, Combat Logistics Force, Shuttle Ship, Station Ship, Combatant Off-Station Time, Safety Stocks, Logistics Planning Factors, Underway Replenishment, Consolidation

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## **DYNAMIC ALLOCATION OF FIRES AND SENSORS**

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The U.S. Army is undergoing significant changes in its force structure and implementation doctrine. This thesis evaluates factors associated with networking assets in a future battle space incorporating Future Combat Systems. An analysis framework was developed designed to assist the Army in current and future evaluation of networked assets and potential configurations of Future Combat Systems at the Unit of Action (UA) and Entity levels. The framework consists of a Discrete Event Simulation Model, Extensible Mark-up Language (XML) input and output modules, and an output analysis package. The simulation model receives scenario inputs from XML files. During the simulation run, the model intermittently calls an optimization package that solves a multi-dimensional knapsack problem to allocate assets based on the current conditions. Once the simulation is complete the model generates XML output that is subsequently processed by an analysis package. The model goes beyond normal implementations of both simulation and optimization by incorporating both simultaneously. The result is an increased level of analysis quality due to the consideration of both stochastic factors and optimization techniques and an analysis architecture that will serve the Army as a basis for the exploration of factors associated with networking assets and system configurations.

**KEYWORDS:** Networked Fires and Sensors, U.S Army Future Combat Systems, Objective Force, Discrete Event Simulation, Mathematical Programming, Optimization, Extensible Mark-up Language (XML), Knapsack Problem

## **THE EFFECTIVENESS OF CORRECTIVE ACTIONS MADE TO RELIABILITY, AVAILABILITY, MAINTAINABILITY AND DEPENDABILITY DEFICIENCIES OF THE MEDIUM TACTICAL VEHICLE REPLACEMENT**

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In an effort to streamline the acquisition process of the Medium Tactical Vehicle Replacement (MTVR), the Combat Support and Logistics Equipment (CSLE) Directorate, Marine Corps Systems Command, took the innovative, but somewhat risky, approach of conducting concurrent developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). Due to numerous reliability, availability, maintainability, and durability deficiencies during the OT&E, the MTVR was not recommended as operationally suitable and had to undergo additional operational testing, thus, negating any savings by conducting concurrent testing. The manufacturer of the MTVR made numerous improvements during the DT&E that were tested during the DT&E and during the second OT&E. In future acquisition programs, an analysis, based on existing data and used in advance or in conjunction with testing, could quantify the risk and provide the Program Manager (PM) and the operational test agency with a way to streamline the OT&E and thereby save time and resources while fielding an effective and suitable vehicle. The purpose of this thesis is to use the recent experience of CSLE scheduling a concurrent DT&E and OT&E of the MTVR as a case study to show how an analytical approach can be used to guide the PM in making decisions regarding the streamlining of testing.

**KEYWORDS:** Reliability, Availability, Maintainability, Dependability, RAM-D, Operational Test and Evaluation, Developmental Test and Evaluation, Medium Tactical Vehicle Replacement, MTVR

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## **DIFFERENTIAL SOLUTIONS USING LONG-RANGE DUAL-FREQUENCY GPS CORRECTION DATA**

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This thesis focused on the accuracy and relevance of applying dual-frequency GPS correction data to compute differential GPS (DGPS) solutions. Analysis was performed to assess the viability of using correction data from reference receivers at extended ranges, 2000-3000 km away, to perform after-the-fact positioning by analyzing stand-alone GPS accuracy versus dual-frequency corrected techniques. This could be extended to real-time operations. The differentially-corrected technique produced more accurate results than stand-alone GPS at all ranges. The stand-alone GPS horizontal root mean square (RMS) accuracy was 5.9 meters while the differentially-corrected RMS accuracy was under 1.5 meters to 2000 kilometers and under 3.0 meters to 3200 kilometers. The process has applicability in determining GPS solutions for long-range military uses. It is possible to use U.S. or Allied GPS assets at long distances from areas of operations to prosecute targets of high interest.

**KEYWORDS:** GPS, DGPS, Stand-Alone GPS, Differential Corrections, Long-Range Correction Data

## **AN ANALYSIS OF FACTORS PREDICTING SUCCESS OR FAILURE: UNITED STATES MARINE CORPS OFFICER CANDIDATES SCHOOL**

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All officers commissioned in the Marine Corps except those from the Naval Academy are required to successfully complete an intense screening program at Officer Candidates School (OCS). The Marine Corps is attempting to improve its officer selection process by determining which candidates it should recruit and send to OCS. In late 2000, the Marine Corps Combat Development Command (MCCDC) commissioned a 67-question survey that has been given to all candidates entering OCS since fall of 2000. The results of this survey are being used to build models to predict the success of candidates based upon responses to the survey. The models created from this survey will be used to build computer desktop tools that recruiting officers may use to assist in selecting the candidates who have the highest probability of success at OCS and in preparing them for the rigors of OCS.

**KEYWORDS:** Surveys, Officer Recruiting, Officer Training, Screening, Military Training, Officer Selection, Officer Candidate, Accession, Predictions

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## **MULTIPLE ADDITIVE REGRESSION TREES: A METHODOLOGY FOR PREDICTIVE DATA MINING FOR FRAUD DETECTION**

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The Defense Finance Accounting Service DFAS-Operation Mongoose (Internal Review-Seaside) is using new and innovative techniques for fraud detection. Their primary techniques for fraud detection are the data mining tools of classification trees and neural networks as well as methods for pooling the results of multiple model fits. In this thesis a new data mining methodology, Multiple Additive Regression Trees (MART) is applied to the problem of detecting potential fraudulent and suspect transactions (those with conditions needing improvement – CNI's). The new MART methodology is an automated method for pooling a “forest” of hundreds of classification trees. This study shows how MART can be applied to fraud data. In particular it shows how MART identified classes of important variables and that MART is as effective with raw input variables as it is with the categorical variables currently constructed individually by DFAS. MART is also used to explore the effects of the substantial amount of missing data in the historical fraud database. In general MART is as accurate as existing methods, requires much less effort to implement saving many man-days, handles missing values in a sensible and transparent way, and provides features such as identifying more important variables.

**KEYWORDS:** Fraud, Data Mining, MART, Classification Trees, Relative Importance of Variables, Missing Values

## **ENHANCING THE SITUATIONAL AWARENESS OF AIRFIELD LOCAL CONTROLLERS**

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In recent years, a number of near midair collisions has shed light on the increased likelihood of mishaps that are partly attributable to traffic density. In air traffic control operations, situational awareness of a local controller at an airfield such as Marine Corps Air Station Camp Pendleton, California, is critical to prevention of catastrophic midair collisions. Spatialized audio technology has the potential to reduce or eliminate temporary losses of situational awareness. Spatialized audio technology allows auditory icons to be presented at perceptual locations external to the head at a complete range of elevation and azimuth locations relative to the listener.

This thesis investigates the use of these spatialized auditory icons to determine if they could be effectively implemented in air traffic control type tasks to benefit local controllers. The research was conducted in the Advanced Auditory Displays Laboratory at NPS. A scenario to exemplify typical airfield operations at Camp Pendleton was written using java-based computer code. A virtual tower environment was created with a head mounted video display, inertial head tracker, and a spatialized audio server. Results indicated that subjects of the experiment responded more rapidly and accurately using spatialized audio.

**KEYWORDS:** Spatialized Audio, Localization, 3D Audio, Air Traffic Control, ATC, Local Controller, Situational Awareness, Auditory Displays, Midair Collision, Analysis of Variance

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## **THE EFFECTS OF REVERSING SLEEP-WAKE CYCLES ON SLEEP AND FATIGUE ON THE CREW OF USS JOHN C. STENNIS**

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This study explores the effects of reversing the work-sleep schedules of the crew aboard the *USS JOHN C. STENNIS*. It also reviews current research in the field of sleep deprivation and the resultant performance decrements in humans. The results of the study indicate that a significant number of sailors have difficulty adjusting to working nights and sleeping days. Additionally, the study finds that individuals working topside have greater difficulty adjusting to the reversed schedule than do their counterparts who work belowdecks. Using a validated model of human performance and fatigue, we demonstrate that the level of fatigue and sleep deprivation observed in this study population significantly reduces individual effectiveness. The recommendations address the need for educating military personnel on the subject of fatigue and sleep logistics, possible fatigue countermeasures, and the need for further research on this topic.

**KEYWORDS:** Circadian Rhythms, Fatigue, Melatonin, Sleep Deprivation, Sleep Loss, Linear Regression Model, Statistical Analysis

## **OPTIMAL ALLOCATION OF ASSAULT SUPPORT AIRCRAFT IN THE SUSTAINMENT OF MARINE CORPS EXPEDITIONARY MANEUVER WARFARE**

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As the United States enters a new millennium, the armed forces, and in particular the Marine Corps, face new challenges in the manner that they deploy and operate. Reductions in both personnel and naval shipping, coupled with an ever-changing world political environment, have led to a dramatic shift in the way that the United States must project its power.

As recent combat operations in Afghanistan have demonstrated, there is a valid requirement for forces to possess the ability to operate from the sea directly to an objective area with minimal or no amphibious landing support. This thesis provides an analysis of the most advantageous assault support aircraft allocation aboard a Marine Expeditionary Unit (MEU) in operations such as this. With the MEU tasked as one of the prominent fixtures in the timely projection of power ashore for the United States, the capabilities (or lack thereof) of assault support aircraft become increasingly important as ship-to-objective distances increase.

The method of finding an optimal composition of aircraft consists of constructing an Assault Support Optimization Model (ASOM). ASOM assists us in prescribing an ideal configuration of assault support aircraft while emulating the dynamic amphibious environment. ASOM analyzes the assignment of several aircraft combinations (4 CH-53E/12 MV-22, 6 CH-53E/10 MV-22, 8 CH-53E/8 MV-22 and 10 CH-53E/6 MV-22) establishing which delivers the greatest ship to objective support to the MEU's Ground Combat Element. The results on various runs of ASOM (at distances of 50nm, 75nm, 100nm and 125nm) identify that the optimal aircraft composition varies with ship-to-objective distances. Overall differences are not dramatic and the researchers do not have further evidence that any aircraft combination clearly outperforms the others. According to the heuristic results obtained in this thesis, it is cautiously recommend that a mix of 6 CH-53E and 10 MV-22 aircraft which, on average, seems to produce better results, and is always the best or second choice regardless of the ship-to-objective distance.

**KEYWORDS:** Operational Maneuver From The Sea (OMFTS), Ship-to-Objective Maneuver (STOM), sustainment, Expeditionary Maneuver Warfare, MV-22, CH-53E, Marine Expeditionary Unit (MEU), Optimization, Network Models

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## **ANALYSIS OF THE EXPEDITIONARY FIRE SUPPORT SYSTEM REQUIREMENT**

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The United States Marine Corps has identified the need to acquire a light, highly mobile, highly transportable indirect fire support weapon system that will have the required lethality, accuracy, and rate of fire to engage and defeat both point and area targets at ranges exceeding 8,000 meters. This weapon has been designated the Expeditionary Fire Support System and will be the primary indirect fire weapon system to support the future vertical assault element of an amphibious assault. In this thesis, a number of candidate systems are examined and evaluated for suitability in meeting Marine Corps requirements. Analysis techniques include multiple criteria decision analysis using key performance parameters specified by the Marine Corps plus additional measures of effectiveness developed in this thesis, and Monte Carlo simulation of a combat scenario. The simulation used the Joint Conflict and Tactical Simulation (JCATS) application. The results of this study were used to support the recommendation of one of the five candidate systems considered.

**KEYWORDS:** Joint Conflict and Tactical Simulation, JCATS, Multiple Criteria Decision Analysis, Analytic Hierarchy Process, Expeditionary Fire Support System, EFSS

## **OPTIMAL AIMPOINTS FOR MULTIPLE GPS WEAPONS RELEASED AGAINST A SINGLE TARGET**

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A GPS weapon is a bomb that is guided to its target using real-time data from satellites of the global positioning system. This thesis develops an algorithm to determine the optimal aimpoints for multiple GPS weapons launched against a single target. Weaponing tools currently used by Navy and Marine Corps aviators do not provide this capability, and typically assume that multiple weapons will be aimed at a single point, the estimated target center. For a given set of aimpoints, the algorithm computes the overall probability of target destruction while accounting for bomb fragmentation, target type, guidance and navigation errors of the weapons, and target-location errors. This computation involves Monte Carlo simulation and numerical integration. Generically, the algorithm reveals that, as the vertical error of the target increases, the optimal aimpoints spread symmetrically from the target in range, at least for the kinds and magnitudes of errors analyzed here. The algorithm, written in Java and running on a Pentium III 600 MHz personal computer, requires approximately 2 minutes to determine optimal aimpoints for all one through four-bomb scenarios.

**KEYWORDS:** Aimpoint Optimization, Weaponing, GPS Weapons, Monte Carlo Simulation, Weapon Errors, Target Location Error

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## **THE USE OF USCG DIFFERENTIAL GPS BEYOND NOMINAL RANGE**

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The United States Coast Guard makes Differential GPS available to all maritime vessels in U.S. coastal and inland waters to ensure 10 meter (2drms) horizontal accuracy. The Coast Guard guarantees this accuracy if the maritime user is within nominal range of the beacon transmitter. Maritime user's can often receive the differential correction beyond the nominal range, but the accuracy begins to degrade as baseline distance increases. After gathering differential corrections from varying distances, at different times of the day, at different latitudes, and different signal strengths, operational statistics have been calculated to describe the Differential GPS accuracy beyond the USCG's nominal range.

**KEYWORDS:** Differential Global Positioning System GPS DGPS USCG Maritime Positioning

## **SPECTRAL ANALYSIS AND SONIFICATION OF SIMULATION DATA GENERATED IN A FREQUENCY DOMAIN EXPERIMENT**

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In this thesis, the frequency domain approach for data farming and the possibility of analyzing complex data sets using data sonification is evaluated. Data farming applies agent-based models and simulation, computing power, and data analysis and visualization technologies to help answer complex questions in military operations. Sonification is the use of data to generate sound for analysis. A frequency domain experiment (FDE) is applied to a combat simulation and analyze the output data set using spectral analysis. The results are compared from the FDE with those obtained using another experimental design on the same combat scenario. Results confirm and complement the earlier findings. An auditory display that uses data sonification to represent the simulation output data set with sound was then developed. The simulation results are considered from the FDE as a waveshaping function and generate sounds using sonification software. The sonified data by their noise, signal, and volume is characterized. Qualitatively, the sonified data match the corresponding spectra from the FDE. Therefore, the feasibility of representing simulation data from the FDE with our sonification is demonstrated. Finally, suggestions are offered for future development of a multimodal display that can be used for analyzing complex data sets.

**KEYWORDS:** Simulation Output Analysis, Frequency Domain Experiment, Sonification, Auditory Display, Design of Experiment, Data Farming

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## AN ANALYSIS OF FUEL EFFICIENCY AS A KEY PERFORMANCE PARAMETER FOR MILITARY AIRCRAFT ACQUISITIONS

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The Acquisition Management System (AMS) of the Department of Defense (DoD) is established to ensure that the needs of the warfighter are fulfilled in the most cost-effective manner possible. The establishment of Key Performance Parameters (KPPs) on Operational Requirements Documents (ORDs) ensures that critical measures of performance are continuously monitored as the identification of a military requirement becomes a fulfilled capability. Threshold values for KPPs identified during an acquisition determine the minimum acceptable level of performance. Failure to meet the threshold level of an individual KPP is grounds for program cancellation. The Chairman of the Joint Chiefs of Staff (CJCS) has mandated that all defense acquisition programs should be kept to a maximum of eight for any individual program. Due to the multi-faceted aspect of modern military aircraft acquisition programs, frequently there are numerous parameters of critical importance. For this reason, any repetition of measure between KPPs must be minimized. The decision of the Principal Deputy Undersecretary of Defense for Acquisition, Technology and Logistics (PUSD (AT&L)) to include fuel efficiency as a KPP on all future acquisitions is an unnecessary exercise for military aircraft. This thesis develops a model in which multiple aircraft are examined flying different mission profiles carrying different weapon payloads. Strong relationships between factors such as combat radius, payload and on-station endurance versus fuel efficiency are demonstrated by regression analysis of the model output. Consequently, any measure of fuel efficiency as a KPP is shown to be redundant. Furthermore, the methodology developed in this thesis may have further uses for the development of logistics planning factors for present and future military aircraft applications.

**KEY WORDS:** Fuel Efficiency, Key Performance Parameter

