DEPARTMENT OF OPERATIONS RESEARCH

Thesis Abstracts

EXPLOITING CONSECUTIVE ONES STRUCTURE IN THE SET PARTITIONING PROBLEM

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The Set Partitioning Problem (SPP) is one of the most extensively researched models in integer optimization, and is widely applied in operations research. SPP is used for crew scheduling, vehicle routing, stock cutting, production scheduling, and many other combinatorial problems. The power and generality of SPP come at a price: An SPP can be very difficult to solve. A real-world SPP often has columns, or rows, with long strings of consecutive ones. This is exploited this with a new preprocessing reduction that can eliminate some variables. A column-splitting technique is also introduced to render a model that can be solved directly or used to bound SPP with Lagrangian relaxation or an exterior penalty method. An SPP row-splitting method is developed that yields a special model that Bender's decomposition may then solve faster than the monolithic SPP. These techniques are demonstrated with well-known test problems from airlines and other researchers. A new U.S. Navy aircraft carrier long-term deployment scheduling model is contributed, using the new techniques to plan with weekly fidelity over a ten-year planning horizon. This improved time fidelity increases planned deployment coverage of areas of responsibility by about ten carrier weeks.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Computing and Software, Surface/Undersurface Vehicles-Ships and Watercraft

KEYWORDS: Set Partitioning, Consecutive Ones, Preprocessing, Problem Size Reduction, Set Packing, Lagrangian Relaxation, Subgradient Optimization, Penalty Method, Benders Decomposition, Aircraft Carrier, Optimization

AN ALGORITHM FOR ENUMERATING THE NEAR-MINIMUM WEIGHT S-T CUTS OF A GRAPH

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An algorithm for enumerating near-minimum weight s-t cuts in directed and undirected graphs, with applications to network interdiction and network reliability is provided. "Near-minimum" means within a factor of 1+(of the minimum for some ((0. The algorithm is based on recursive inclusion and exclusion of edges in locally minimum-weight cuts identified with a maximum flow algorithm. A polynomial-time complexity result when (= 0, and for (> 0 the demonstration of good empirical efficiency is proven. The algorithm is programmed in Java, run on a 733 MHz Pentium III computer with 128 megabytes of memory, and tested on a number of graphs. For example, all 274,550 near-minimum cuts within 10% of the minimum weight can be obtained in 74 seconds for a 627 vertex 2,450 edge unweighted graph. All 20,806 near-minimum cuts within 20% of minimum can be enumerated in 61 seconds on the same graph with weights being uniformly distributed integers in the range [1,10].

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Near-Minimum Cuts, Cut Enumeration, Minimum Cuts, Network Interdiction

OPTIMIZING PROCUREMENT PLANNING OF NAVY SHIPS AND AIRCRAFT

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The United States Navy Chief of Naval Operations Assessment Division (N81) is responsible for planning long-range capital expenditure on ships, submarines and aircraft. This planning is complicated, involves billions of dollars over decades, and determines future Navy capability. Navy force structure analysts have to balance: yearly budgets; requirements, current inventory, and procurement options for ships, submarines, and aircraft; and capacity and workforce levels of shipyards and factories. N81 Navy analysts currently use the Extended Planning Annex/Total Obligated Authority (a spreadsheet that estimates the financial impact of any complete future plan) to assist them with their complex planning. The Capital Investment Planning Aid (CIPA) is a prototypic optimization model, limited in scale, previously developed to demonstrate the benefits of augmenting EPA/TOA with optimization. This thesis introduces Generalizing Procurement Planning for Naval Ships and Aircraft (GENSA), which extends CIPA. GENSA is tested with a 30-year planning horizon with 29 mission areas, 45 ship classes, 39 aircraft types, 13 production facilities, and four categories of money. A current base case and an excursion demonstrate GENSA can be used to address exigent issues optimally.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Integer Linear Programming, Military Capital Budgeting, Optimization, Force Structure

APPLICATION OF A SYSTEM-BASED INVENTORY MODEL FOR MARINE CORPS REPAIRABLE PARTS

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A critical component of the Marine Corps' self-sustainment capability is its ability to procure and repair components for its ground equipment fleets. Secondary repairables consist of components that can be repaired, and for which repair is generally more economical and timely than purchase. The Marine Corps currently maintains spare repairable parts at seven principal locations, each operating independently of the other. There is excess inventory Service-wide because of the isolation of the inventories and because of mathematical flaws in the Marine Corps' sparing methodology. The Marine Corps is seeking to centralize the management of secondary repairables and is considering options that include centralizing responsibility and funding (while keeping the inventory model as it is) and changing the inventory model as well as the responsibility and funding. This thesis demonstrated that a centralized, "enterprise-wide" model of the inventory is superior to a decentralized one. Measures of comparison are total inventory cost and end-item availability. Stock levels calculated by both the current model and a commercial application called VMetric(tm)-XL were evaluated. For a selected end-item, the current model produces stock levels totaling $25.9M in inventory and achieves 89.1% availability. For the same level of availability, Vmetric recommends stock levels totaling $2.9M, a stunning 89% reduction in cost. These results are explained and implications for Marine Corps logistics support are suggested.

DoD KEY TECHNOLOGY AREAS: Manufacturing, Science and Technology

KEYWORDS: System-Based Inventory, Marine Corps, Self-Sustainment Capability, Repairable Parts

ANALYSIS OF SELF-REPORTED SLEEP PATTERNS IN A SAMPLE OF U.S. NAVY SUBMARINERS USING NONPARAMETRIC STATISTICS

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Fatigue contributes to increased accidents and mishaps and reductions in human performance. Inadequacies in the quality and quantity of sleep amongst U.S. Navy submariners can have detrimental effects on command and control functions, and can degrade overall human performance. The purpose of this study is to gain insight into the sleeping habits of U.S. Navy submariners. Using data supplied by the Naval Submarine Medical Research Laboratory, this study evaluates what a sub-sample of this population think about their sleep habits and will determine if there are differences in the reported amount of sleep between sailors in four different operational environments: 1) at sea, 2) in port, 3) on shore duty, and 4) on leave. The statistical analysis showed that there are discernable differences in the quality and quantity of sleep onboard U.S. submarines. There is a positive correlation between the amount of sleep obtained and the desired amount of sleep to function at every operational condition. Of the four operational conditions evaluated, the 'at sea' condition is the most different from all other conditions. Submariners reported getting less sleep while 'at sea' than other conditions. Finally, there is a positive correlation between the amounts of sleep obtained (both total sleep and uninterrupted sleep) and the desired amounts of sleep needed to function in every operational condition leading to the inference that subjects who report needing more sleep do indeed get more sleep. When in the 'at sea' condition, this correlation was much weaker indicating that subjects have much less control over the amount of sleep they get when deployed.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Human Performances, Sleep Patterns, Fatigue, Submariners

OPTIMIZING THE NUMBER AND EMPLOYMENT OF COMBAT LOGISTICS FORCE SHUTTLE SHIPS, WITH A CASE STUDY OF THE T-AKE SHIP

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An optimization model that prescribes how Combat Logistics Force shuttle ships --- such as the new T-AKE 1 Lewis & Clark class auxiliary cargo-and-ammunition ship --- should be employed to sustain any number of deployed aircraft carrier (or other) battle groups (BGs) throughout a major theater war are presented. A variety of unclassified deterministic scenarios are developed involving between one and six BGs transiting worldwide to, e.g., the Baltic, the Arabian Sea, or Korea. Daily consumption of dry stores, ship fuel, aviation fuel, and ordnance is estimated. For each shuttle ship, it is assumed that the first consolidation visit to a BG can occur anywhere, but thereafter we track the shuttle ship back to a port to reload is tracked, and then back to rendezvous with some BG, and so forth. To precisely account for transit times, a global sea route model is presented that connects all resupply ports to waypoints, and distinguishes slow-speed passages through canals and restricted waterways, and legs that preclude BG consolidation visits. The objective is to deliver maximal quantities, and to avoid ever falling below BG safety stocks. The results tell how many shuttle ships are needed, and how to employ them.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Optimization, Combat Logistics Force Shuttle Ships, T-AKE Ship

THE IMPACT OF TURN AROUND TIME IN BRAZILIAN NAVY INVENTORIES

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This thesis analyzes how the operation of helicopters produced and supported by manufacturers in various countries affect Brazilian Navy repairable inventories levels and costs. The research is based on a scenario where the Brazilian Navy operates 68 helicopters, manufactured by contractors in the U.S., France, England and Italy, and the Brazilian Navy relies on these manufacturers for depot-level maintenance. A simulation model representing the repair process of a group of critical helicopter components and measure the turn-around time (TAT) was developed. A readiness based model was also developed to find the optimal inventory level of the selected group of helicopter components to achieve a desired operational availability under these TATs. The results were applied to a spreadsheet model to find the differences in spare levels and associated costs necessary to operate the helicopter fleet. The research concludes that the helicopter's source has a substantial impact on repairable inventories levels and costs. Furthermore, this impact is large enough to influence decisions in the Brazilian Navy acquisition process of equipment and weapons systems.

DoD KEY TECHNOLOGY AREA: Manufacturing, Science and Technology, Other (Logistics)

KEYWORDS: Inventory Management, Operational Availability, Simulation Modeling, Transportation, Aviation Depot-Level Maintenance

ESTIMATING HULL COATING THICKNESS DISTRIBUTIONS USING THE EM ALGORITHM

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The underwater hull coating system on surface ships is comprised anti-corrosive (AC) and anti-fouling (AF) paint. The AF layers are designed to wear away, continuously leaching cuprous oxide to inhibit marine growth. The thickness of the AF paint layers determines the expected service life of a coating system. Thus, it is important to assess the thickness of the AF layers to determine if the current hull coating system is sufficient. The Naval Ship Technical Manual (NSTM) provides specific guidelines as to how much AF paint should be applied. Unfortunately, the AF layers cannot be measured directly. The distribution of total paint thickness measurements is currently used as a proxy for the distribution of the thickness of the AF paint layers when determining if the existing coating system meets the hull coating requirements. A remedy for this situation is proposed. A non-parametric maximum likelihood estimator for the cumulative distribution function of the AF layers, based on the EM algorithm, has been developed. Monte Carlo simulation is used to study the properties of this statistical approach for estimating the AF thickness. This model can be used to help decide if sufficient AF paint is on the underwater hull of a ship.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures, Ships and Watercraft

KEYWORDS: Deconvolution, EM Algorithm, Anti-Fouling Paint, Underwater Hull Coating System

PERFORMANCE METRICS FOR CORRELATION AND TRACKING ALGORITHMS

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Military commanders require situational awareness to support real-time decision-making. To obtain information on possibly hostile entities in an area of interest, surveillance systems, which receive information from sensors such as radars, intelligence, and other sources, are often used. One of the objectives of surveillance systems that track aircraft is the formation of a Single Integrated Air Picture (SIAP), that represents a coherent resolution of information. Correlation is the process by which sensor measurements and other information are combined to keep the SIAP up-to-date in real time. A correlator, which is the software implementation of a correlation methodology, must resolve ambiguities and conflicting information to provide an operationally useful synthesis of surveillance data. Possible ambiguities include missed tracks, extra tracks, or position and velocity errors. The metrics developed in this thesis are designed for use in evaluating the performance of air surveillance systems, of which correlators are an integral part. Maneuvering or closely spaced aircraft pose difficult issues for air surveillance systems. These are addressed by the performance metrics. Using scripted test scenarios in a modeling and simulation environment, comparisons of correlators can be made using nonparametric statistical methods. An experiment constructed in this manner can be used to support acquisition decision-making.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Modeling and Simulation, Sensors

KEYWORDS: Correlator, Correlator Performance Metrics, Surveillance Systems, Single Integrated Air Picture (SIAP)

EXPLORING THE VALIDATION OF LANCHESTER EQUATIONS FOR THE BATTLE OF KURSK

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This thesis explores the validation of Lanchester equations as models of the attrition process for the Battle of Kursk in World War II. The methodology and results of this study extend previous validation efforts undertaken since the development of the Ardennes Campaign Simulation Data Base (ACSDB) in 1989 and the Kursk Data Base (KDB) in 1996. The KDB is a computerized database developed by the Dupuy Institute and the Center for Army Analysis from military archives in Germany and Russia. The data are two-sided, time-phased (daily), highly detailed, and encompass 15 days of the campaign. The primary areas of analysis are the effect of using purely engaged forces in parameter estimation and the effect of force weighting in forming homogeneous force strengths. Based on the numbers of personnel, tanks, armored personnel carriers, and artillery, three different data sets were constructed: all combat forces in the campaign, combat forces within contact that are both engaged and not engaged, and combat forces within contact that are engaged. In addition, a weight optimization program using a steepest ascent algorithm was developed and utilized. Findings indicate that Lanchester-based models provide a considerably better fit for data sets composed only of forces that are actively engaged. Also, Lanchester's linear model appears to provide the best fit to the Battle of Kursk data. Finally, optimization of force weights does not significantly improve the fit of Lanchester models.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Lanchester Equations, Battle of Kursk, Combat Models, Attrition, Model Validation

RE-ENGINEERING THE ENROLLMENT MANAGEMENT SYSTEM AT THE MONTEREY PENINSULA UNIFIED SCHOOL DISTRICT (MPUSD)
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This thesis establishes a Forecasting Enrollment Management (FEM) System within the Monterey Peninsula Unified School District (MPUSD). In particular, it examines the effect the forecasting of student enrollment since the untimely departure of the Deputy Superintendent (DepSup) who had performed the function as Chief Enrollment Official for over two decades. The closure of the Fort Ord Army Facility had a significant impact on the accuracy of enrollment projections and inadvertently affected the funding for special program allocations and staffing. The MPUSD has within its control twenty-three schools that service over 12,000 students each year using public funds. Four schools are located within military housing communities and typically service the school-age military dependents residing nearby. Each year's funding is determined by an estimate projected from the previous year's enrollment. The District is required to provide a budget request by April 15th of each school operating year. The school district currently has no computational model adequate for projecting student enrollment; MPUSD uses a working group process to achieve its objective. A model that can more precisely project the number of students in each future year is developed; it can provide a more efficient enrollment management process and provide the necessary checks and balances for the current method. The thesis considers independent community related variables and historical data, and shows that prior-year enrollment figures can forecast future-year enrollment projections with smaller variance than the current working group method.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Enrollment, Enrollment Management, Forecasting, Data Analysis, Data Collection, Process Engineering, Quality Assurance, Continuous Process Improvement

A PARAMETRIC COST MODEL FOR ESTIMATING OPERATING AND SUPPORT COSTS OF U.S. NAVY AIRCRAFT
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This study provides parametric O&S cost models for future US Navy aircraft acquisition programs based on physical and performance parameters. The proposed parametric cost models provide decisionmakers with a tool for developing rough-order-of-magnitude annual O&S cost estimates for future U.S. Navy aircraft acquisition programs. The historic aircraft cost data was provided by the Naval Center for Cost Analysis (NCCA) in a spreadsheet format and the data were extracted from the Navy Visibility and Maintenance of Operating and Support Cost (VAMOSC) data warehouse. After validating the assumption that the average annual O&S cost for any aircraft type/model/series is constant from year to year, cost estimating relationships are developed. The first model developed is based on multivariate regression. In this case, forward stepwise regression was used to find the model with the best fit. Since the multivariate regression model turns out to be impractical, having more than 30 variables in the equation, a tree-based

model is presented as an alternative. Additionally, single variable cost estimating relationships are formulated based on the physical and performance parameters length, weight, and thrust.

DoD KEY TECHNOLOGY AREA: Other (Cost Analysis)

KEYWORDS: Cost Estimation, Operating and Support Cost, Aircraft, Regression, Tree Models

USING ON-LINE ANALYTICAL PROCESSING AND DATAMINING TO ESTIMATE EMERGENCY ROOM ACTIVITY IN DOD MEDICAL TREATMENT FACILITIES IN THE TRICARE CENTRAL REGION

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On-line Analytical Processing (OLAP) and datamining can greatly enhance the ability of the Military Medical Treatment Facility (MTF) emergency room (ER) manager to improve ER staffing and utilization. MTF ER managers use statistical data analysis to help manage the efficient operation and use of ERs. As the size and complexity of databases increase, traditional statistical analysis becomes limited in the amount and type of information it can extract. OLAP tools enable the analysis of multi-dimensional data, which can give the user access to previously undiscovered information. Data mining has the capability to break large sets of data down into groups by classifications, associations, and clusterings to transform previously meaningless data into useful information.

This research presents a brief overview of the DoD medical system, OLAP, and datamining. OLAP and datamining tools then analyze a data set containing two years of MTF ER data from the TRICARE Central Region. The results of these analyses provide insight on the predictive capabilities, advantages, and disadvantages of applying OLAP and datamining to MTF ER data.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: On-Line Analytical Processing (OLAP), Data Mining, Medical Treatment Facility (MTF), Emergency Room

JAVAMIX: A TACTICAL DECISION AID TO EVALUATE MINEFIELD CLEARANCE PLANS

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A Tactical Decision Aid (TDA) for mixed minefield clearance, JAVAMIX, was designed, developed and tested. The TDA uses a Monte Carlo Simulation and it is based on the Monte Carlo option of the TDA MIXER (Washburn, 1995). The JAVAMIX Graphical User Interface (GUI) allows the user to introduce different plans based on the sweep and resource types available and mine types expected. To clear the minefield the user is asked to choose a parameter file and to introduce a plan. Output tables are presented in a DOS window and permit the user to easily visualize if the chosen plan is tactically executable. The design of the system permits future developments such as the implementation of MIXER's other options and the introduction of new parameters.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Tactical Decision Aid for Mine Warfare, Java, Graphical User Interface

A COST BENEFIT ANALYSIS OF SUPPLYING CONSUMABLE MATERIALS BY READY SUPPLY DEPOT (RSD) VERSUS COMMERCIAL VENDORS

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The purpose of this study is to examine the current Philippine Fleet (PF) method of supplying consumable materials to Fleet units via a Ready Supply Depot (RSD). The study desires to determine the most cost-effective method of delivering the services currently provided by the RSD in order to fully maximize the use of Fleet resources without sacrificing mission effectiveness. This thesis focuses on the cost the Navy pays to the supplier and all direct and indirect costs of the RSD operation. This study compares the total price of each item inventoried at RSD to a similar item sold by commercial vendors in the Cavite City and Manila area. The difference in price is multiplied by past demand to determine the excess cost to consumers of acquiring consumables from RSD instead of directly from commercial vendors. Additionally, results from RSD consumer surveys are used to assess the service benefits provided by RSD, as seen by its customers. The research results show that the compared items are less expensive to the customer when purchased at RSD. However, it also shows that it is more costly for the government to provide these items via RSD. Furthermore, a customer survey indicates that the RSD customers are not satisfied with the selection, quality, availability, and customer service levels present at the RSD. As a consequence, the recommendation is made to eliminate the Ready Supply Depot (RSD) operation and allow the RSD customers to use commercial vendors for their non-military consumable item needs.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Consumables, Ready Supply Depot, Inventory Management

AN ANALYSIS OF ROTARY WING OPERATIONS IN URBAN COMBAT USING THE JCATS COMBAT MODEL

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The trend of the world's population toward urban areas in the littoral region and increased likelihood of urban conflict has shifted the focus of the military to operations in the urban environment. There is interest within the DoD to evaluate the ability of U.S. forces to operate in the urban environment. In recent years, the Marine Corps has spent considerable time and effort conducting analysis on and development of urban warfare Tactics, Techniques and Procedures (TTPs). There is a need to refine and improve rotary wing operations in this setting.

This thesis modeled and conducted analysis on rotary wing (RW) operations in urban combat using the Joint Conflict and Tactical Simulation (JCATS) combat model. Focus was given to aircraft survivability to evaluate varying tactics and techniques to aid in development of Marine Corps RW TTPs. Thesis objectives were to evaluate rotary wing (RW) survivability in urban combat, determine the major factors impacting on RW survivability, give insight into the development of Marine Corps urban RW TTPs, and to evaluate JCATS as an urban combat modeling tool.

A fractional factorial design was used to vary tactical factors and evaluate their effects. Measures of Effectiveness (MOEs) for evaluation of these effects included Blue RW kills and Blue RW detections.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Urban Conflict, Urban Warfare, Rotary Wing Operations, Urban Combat Modeling Tool

STATISTICAL ANALYSIS OF NAVAL AVIATION DEPOT REPAIR CYCLE TIME REDUCTION FOR THE F/A-18 C/D AIRCRAFT

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Reducing U.S. Navy inventory control problems associated with the F/A-18 C/D aircraft is critical to maintaining squadron readiness while minimizing procurement and repair costs. The Navy's Inventory Control Point has designed its Carcass Express program to ensure that critically short depot level repairables are serviced more quickly. The program was initiated on the S-3 Viking aircraft in 1999. Subsequently, the number of constrained carcasses was reduced by 40 percent, and the average depot repair cycle time was reduced by 12 days. This thesis attempts to quantify the savings that can be realized by instituting the Carcass Express program for the F/A-18 C/D. Data for F/A-18 C/D repairable items that were identified as having insufficient carcasses for repair to meet current demand levels are analyzed. These repairable items have high dollar values and significant backorders severely impacting squadron readiness.

It is shown that the Carcass Express program would provide an additional accrual of inventory over a four-year period for the items studied. The required funding needed to support the deficit between items available from the depot repair cycle and forecast quarterly demands would decrease. The Carcass Express initiative would improve the predictability of the Depot Repair Cycle by reducing repair cycle variability. This ultimately would lead to better inventory management.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Materials, Process, and Structures, Modeling and Simulation

KEYWORDS: Forecasting, Statistics, Repairable, Inventory, Operations

PLANNING U.S. PACIFIC COMMAND WARTIME FUEL DISTRIBUTION

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The Commander-in-Chief, U.S. Pacific Command (USCINCPAC) Joint Petroleum Office (JPO) plans wartime fuel distribution in the U.S. Pacific Command (USPACOM). The USCINCPAC JPO uses manual and spreadsheet based computational methods to assess fuel distribution infrastructures and Operational Plan (OPLAN) supportability. This thesis provides an optimization-based fuel distribution system consisting of linear programming models. Entitled Pacific Petroleum Distribution Model (PPDM), represents the USPACOM fuel distribution infrastructure and accounts for fifty Defense Fuel Support Points (DFSPs). Optimization models provide assessments of distribution capacity and present quantitative rationale to assist JPO in determining distribution requirements while planning and validating wartime fuel support. A series of analyses on notional data demonstrate PPDM's ability to conduct assessments. With OPLAN requirements of 94,000 MBBLs over the 120 day period, PPDM initially identifies significant shortages accumulated before 90 days. Subsequent PPDM analyses show alternatives to optimally schedule additional deliveries and reduce these shortages.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Optimization, Decision Support, Fuel Distribtion

ANALYSIS OF MAINTENANCE RECORDS TO SUPPORT PREDICTION OF MAINTENANCE REQUIREMENTS IN THE GERMAN ARMY

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Today the German Armed Forces are faced with a broad, varied and graduated range of tasks including missions outside Germany. A major challenge in planning the force structure for missions like the one in Kosovo is to predict the required maintenance capacities. This thesis conducts an exploratory data analysis of maintenance records of the German Army, using the wheeled reconnaissance tank "Luchs" as an example. The question under investigation is whether or not data from the maintenance records can be used to support a future "maintenance prediction tool." It is shown that repairtime distributions extracted from the data can be used to model the repair process in a simulation. The Weibull distribution family, which is commonly used in reliability applications, proved flexible enough to simulate repairtimes and workorder supply times. Implementing these results in a simulation of the repair process will improve the accuracy and quality of the simulation output. In addition, this thesis discusses data quality issues and makes design suggestions for a new maintenance organization software. Data problems can be minimized if the problems identified in this study are aggressively attacked during the design and implementation phases of the new software.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Other (Logistics)

KEYWORDS: Maintenance, Repairtime Distribution, Data Quality, German Army

A MULTI-ATTRIBUTE DECISION SUPPORT MODEL FOR 'BEST VALUE' SOURCE SELECTION

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For decades, the federal government has grappled with the issue of how to determine the "best value" offer for services from among competing contractors vice awarding contracts based on lowest bid only. This thesis develops a risk-adjusted cost evaluation decision support model for use in government best value source selection. The thesis presents the Best Value Evaluation Methodology (BVEM), which assists the source selection team throughout the source selection process. BVEM encompasses the fundamentals of "best value" analysis including risk assessments of cost, schedule, technical feasibility, and contractor past performance. BVEM generates a multi-attribute utility measurement (MAUM) score for each proposal based upon the assessed risk. The MAUM score is used to define Triangular and Beta probability distributions for use in Monte Carlo simulations to determine risk-adjusted cost estimates. BVEM also emphasizes the use of upper confidence levels as a better comparison tool for best value than singular point estimates. Additionally, the thesis develops a software implementation of BVEM, called the Cost-Risk Enhanced Source Selection Evaluation Tool (CRESSET). Based on Microsoft Excel and Palisade @RISK software, CRESSET may be used to generate appropriate risk distributions, weighting criteria, quantitative results and visual displays of relative risk for each proposal for use in best value analysis. CRESSET is also useful for preparing more realistic budget estimates.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Contracting)

KEYWORDS: Acquisitions, Contracting, Best Value, Proposal Evaluation, Cost-Risk Analysis, Simulation

ORGANIZATIONAL CLIMATE AND ITS RELATIONSHIP WITH AVIATION MAINTENANCE SAFETY

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Naval Aviation is continually looking for ways to reduce its mishap rate. Recognizing a growing concern for issues related to aging aircraft, focus has expanded to include maintenance operations. It is accepted that human error is a causal factor in at least eighty percent of all mishaps, with maintainer, line, or facility-related factors accounting for one out of five major mishaps. One of several actions taken to reduce the mishap rate is the Maintenance Climate Assessment Survey (MCAS). Created to give Naval Aviation unit commanding officers a sense of the maintenance climate of their unit, the MCAS reveals the maintainer's perception of safety climate. Beginning in July 2000, the MCAS administration became available via the Internet. This thesis analyzes the results of the first 2,180 responses recorded via the Internet version of MCAS. Findings include: a) administration of the Internet-based MCAS yields results similar to the paper-and-pencil version; b) differences were detected among the participating units and the Model of Organization Safety Effectiveness components; c) the relationship between MCAS score and Incident Rate, although slightly negative, is indistinguishable from random variation; and d) there was no evidence that demographics bias the results. These findings could be accounted for by the fact that a unit's safety climate typically improves after a mishap. Requiring all units to complete the survey annually would allow tracking over time to uncover trends. One area for further research is investigating the feasibility of adapting the MCAS to afloat and ashore units.

DoD KEY TECHNOLOGY AREA: Other (Naval Aviation)

KEYWORDS: Safety Climate, Human Error, Maintenance

HETEROGENEOUS SALVO MODEL FOR THE NAVY AFTER NEXT

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The Navy Warfare Development Command has taken the lead in studying needed Capabilities for the Navy After Next. Amongst the ideas they are considering are innovative special purpose littoral warfare platforms as well as alternative relationships between platforms, sensors, weapons, and information. This thesis presents a low-resolution model for analysis of Navy After Next concepts and demonstrates the potential use of the model. Presented is an adaptation of the existing Hughes Salvo Model which had been limited to analysis of engagements between forces composed of identical units, i.e., homogeneous forces. This heterogeneous extension is an analytical device that captures the unique combat characteristics of individual units. The model helps decisionmakers understand salvo warfare of heterogeneous forces by simplifying the complex relationships within and between forces during battle. Using a previous work that tested Hughes' model, the accuracy of this heterogeneous salvo model is examined by comparing results. This thesis further demonstrates the strength of the heterogeneous salvo model through an analysis of a hypothetical campaign scenario and through an examination of alternative tactics.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Combat Models, Salvo Model, Hughes Salvo Model, Naval Tactics, Campaign Analysis

AN ANALYSIS ON THE SURVIVABILITY OF LAND ATTACK MISSILES (LAM)

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This thesis develops a process to assist military planners in assessing and evaluating the effectiveness of land attack missiles. The aforementioned process contains the means to address the variety of important issues and concerns that are associated with the employment of such land attack missile systems. The Department of the Navy is proposing a new land attack missile that will be employed by the Destroyer of the 21st Century (DD 21) to assist in performing Naval Surface Fire Support missions for Marines and Army troops operating ashore. This research focuses on using the Extended Air Defense Simulation (EADSIM) to estimate the probability of LAM survival for different variants of land attack missiles against various threats. The analysis concludes that the most survivable cruise missile variants have an altitude of at least 4,000 meters, speed of at least 1,610 knots, and stealthy enough to limit the enemy air defense site detection range to 1% of its maximum range. Survivable ballistic missile variants have a lofted trajectory, speed in the 2,577 knot range, and stealthy enough to limit the enemy air defense site detection range to 10% of its maximum range. The data in this thesis is from unclassified sources, but the process can be applied with classified numerical parameters.

DoD KEY TECHNOLOGY AREA: Air Vehicles, Battlespace Environments, Conventional Weapons, Sensors, Modeling and Simulation

KEYWORDS: Land Attack Missile, Advanced Land Attack Missile, Cruise Missiles, Ballistic Missiles, Missile Survivability

OPTIMIZING POSITIONING OF NAVY WHOLESALE INVENTORY

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Naval Inventory Control Point (NAVICP) currently manages more than 210,000 line items to supply 957 customers worldwide. NAVICP positions these items within a distribution network of 22 Defense Depots operated by the Defense Logistics Agency (DLA). NAVICP plans to reduce supply system distribution cost by optimizing their use of this distribution network. This thesis develops a heuristic algorithm that optimally positions line items to serve historical requisitions by Naval units over an 18-month period. Repositioning minimizes distribution costs subject to constraints on customer wait time and depot capacities. This model suggests a distribution scheme for 32,521 unique wholesale items from 22 depots to 126 aggregated customer regions worldwide. The Navy can reduce distribution cost by better strategic positioning of Navy wholesale inventory within the existing distribution network. The Navy can also achieve savings by positioning stocks at just a few locations, rather than at many, and by positioning items together in aggregate product groups, a policy that is widely admired in logistics.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Inventory Positioning, Location Problem, Optimization, Logistics

MODELING AND SIMULATION IN SUPPORT OF OPERATIONAL TEST AND EVALUATION FOR THE ADVANCED AMPHIBIOUS ASSAULT VEHICLE (AAAV)

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This thesis documents a simulation model developed to assist in the planning of Operational Test and Evaluation (OT&E) of the Marine Corps' Advanced Amphibious Assault Vehicle (AAAV). The model simulates a platoon of AAAVs in an amphibious assault, using Operational Maneuver From the Sea (OMFTS) techniques, supported by elements of a Marine Expeditionary Unit (MEU) aboard amphibious ships offshore. The emphasis of the model is on suitability issues, specifically operational availability, maintainability, and supportability. In particular the effect of logistical support for one AAAV on the ability of the platoon to complete a mission. The purpose of the simulation is to gain insight into important and highly sensitive factors that, when changed slightly, have large effects on the platoon of AAAV's ability to perform its mission.

The results of the model show that, the assumed form of the distribution of failure times for a single AAAV is the most important aspect of reliability test data. Simply calculating the mean time to failure (MTTF) from data and using an exponential model is inadequate. Even if an observed or estimated MTTF is within an acceptable requirement threshold level, if it is characterized by a high or even moderate number of infant failure times, then the platoon's ability to perform its mission is substantially impeded. Other factors that are of importance are the procedure by which a failed AAAV is rescued and repaired, and the average length of each repair.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human-Systems Interface

KEYWORDS: Advanced Amphibious Assault Vehicle, AAAV, Military Test and Evaluation, Decision Analysis

ENHANCING REAL-TIME TOMAHAWK PREDESIGNATION TO DIAGNOSE CONFLICTS, PRESCRIBE IMPROVEMENTS, AND PLAN MULTIPLE STRIKES

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Tasking Tomahawk Land Attack Missiles (TLAM) to firing units is complex and time-consuming. This thesis shows how to help the Tomahawk Strike Coordinator (TSC) find efficient, logical and reproducible predesignations (allocations of TLAM tasks to firing units). Previous Naval Postgraduate School work has developed an optimal predesignation and a fast heuristic. However, there may be particularly constrained scenarios in which a complete allocation of tasks to firing units cannot be made. Based upon the cause for the unallocated tasks, the TSC must be able to diagnose and prescribe modifications to unassigned tasks efficiently and logically to arrive at the best allocation possible. This thesis embellishes the fast heuristic to diagnose why a task cannot be allocated and to provide the TSC with recommended modifications to tasks (e.g., change time of launch and/or eliminate redundant task parts). In addition, we improve the fast heuristic to allow sequential allocation of an arbitrary number of sets of tasks. These enhancements offer the TSC new capability to quickly and effectively plan strike warfare.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Optimization, Tomahawk Land Attack Missiles, Tomahawk Strike Coordinator

A MULTI-COMMODITY NETWORK-BASED HEURISTIC FOR THE SHIP-TO-OBJECTIVE MANEUVER

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The Marine Corps is responsible for developing amphibious doctrine and techniques, and conducting amphibious operations. The most critical phase of an amphibious operation is the Ship-to-Objective Maneuver (STOM), the scheduling of which must account for heterogeneous transport aircraft and serials, varied ship-to-shore distances, limited numbers of ship deck spots, and diverse capacities of landing zones ashore. This complex planning is currently done without computer assistance. To expedite the planning and scheduling of the aviation portion of the STOM, this thesis presents the Air Plan Construction Heuristic (APCH). Given a commander's scheme of maneuver and available aircraft, the APCH schedules routes, loads, and departure and arrival times for all aircraft. This heuristic attempts to minimize the time required to deliver all serials, subject to aircraft and ship deck spot availability, and the capacity of helicopter landing zones ashore.

To illustrate the operational planning potential of the APCH, an Air Plan for a MEU scenario is generated, and then compared to a manually-generated schedule. To demonstrate the prospective use of the APCH as an analytical tool, we evaluate the time required to deliver all serials ashore as a function of ship-to-shore distance.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Amphibious Operations, Ship-to-Objective Maneuver, STOM, Multi-commodity Network

STATISTICAL VALIDATION OF TRACK QUALITY NUMBERS FOR JOINT INTEROPERABILITY TESTING OF THEATER AIR AND MISSILE DEFENSE FAMILIES OF SYSTEMS

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Joint interoperability is fundamental to the effectiveness of a Theater Air and Missile Defense (TAMD) Family of Systems. Under the Joint Data Network concept, systems compete for reporting responsibility of a possible missile track by issuing track quality numbers related to the covariance matrix of the estimated position and velocity. The system that reports the highest track quality number is assigned reporting responsibility for the track. Verifying that reported track quality numbers are accurate is an integral part of an interoperability test and evaluation program for a TAMD family of systems. In this thesis a framework for measuring the accuracy of track quality numbers, based on reported position and velocity, is described. The framework is applicable to family of system tests consisting of either live missile tracking or modeling and simulation data. Issues that arise in assigning truth objects to tracks are discussed. Measures of performance are proposed based on statistical tests to describe the accuracy of track quality numbers for each system under evaluation in family of systems interoperability testing. Applying the metrics to missile data reveals instances when the reported track quality numbers by TAMD systems are too high.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation, Command, Control and Communications

KEYWORDS: Tracking, Trajectory Estimation, Track Quality, Interoperability, Test and Evaluation, Theater Air and Missile Defense

EVALUATION OF COMBAT SERVICE SUPPORT LOGISTICS CONCEPTS FOR SUPPLYING A USMC REGIMENTAL TASK FORCE

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One of the primary responsibilities of a Marine Corps Combat Service Support Element (CSSE) is to provide water, fuel, and ammunition requirements for the primary task forces and other Marine Expeditionary Force (MEF) elements. This thesis evaluates existing and proposed concepts on how to best use the CSSE resources of a Force Service Support Group to transport supplies to Regimental Combat Teams over constrained networks with time constraints. A model was developed that optimizes the use of resources, assets, and network routes. The model first solves a capacitated vehicle routing problem, where a set of customers has to be served by a fleet of vehicles within a certain time. The stochastic aspects of the problem are modeled through the use of a discrete event simulation that uses the results of the optimization model. The optimization model goes beyond the traditional routing problem by accounting for special features such as vehicle capacity for each commodity and cargo incompatibility (e.g. fuel and ammunition). The model includes both optimization of routes and simulation of stochastic elements. As a result, this thesis establishes a basis for future studies involved with modeling new concepts in Combat Service Support.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Marine Corps Combat Service Support Element, Combat Service Support Logistics Concepts, Optimization

A POISSON REGRESSION ANALYSIS OF THE ACADEMIC SETBACK IN NAVAL TRAINING DEADTIME

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The dead time in a Naval Training Pipeline is defined as time spent by students enrolled in training doing things other than training. The effect of dead time has been to decrease the utilization of personnel to under 70% in recent times. Four years (1996-1999) of data have been selected for study. The Academic Setbacks for course with CDP identifier 6400 has been chosen for initial work and model building. The methods developed for this case will be applied to Academic Attrition and Instruction Interruption to the extent possible. The exploratory analyses will seek to discover internal temporal patterns of setbacks. The goal is to build methodology for identifying sets of time intervals that exhibit the larger setback and attrition rates.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: Poisson Regression, Training Deadtime, Maximum Likelihood

RELIABILITY AND LIFE DATA ANALYSIS FOR AN/AAS-44(V) FORWARD LOOKING INFRARED (FLIR) SYSTEM TO FORECAST H-60 OPERATIONAL AVAILABILITY

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The AN/AAS-44(V) Forward Looking Infrared (FLIR) System used on the Navy's H-60 Helicopter is taking on an increasing role in helicopter operations and is an important element in the Armed Helicopter design concept. Since its initial acquisition in 1997, the FLIR has been unable to achieve pre-acquisition reliability requirements. Coupled with the high cost of FLIR components, the short times to failure of the FLIR impact Operational Availability (Ao) and cause funding for spares to exceed budgeted levels.

The ability to properly estimate system behavior provides the foundation to adequately fund the level of spares necessary to achieve a level of Ao and to assess the improved system reliability that would result from a system redesign. Two models are developed. The first model assumes the times between failures are independent identically distributed exponential for each unit with different means for individual units. The second model assumes that the times between failure are independent identically distributed and uses the empirical distribution. Both models are simulated. Simulation results are used to estimate the reliability improvement that a proposed system redesign will have. Simulation results also are used to estimate Ao as a function of the number of spares for a carrier battle group. Comparison of simulation results to the Navy's inventory model suggests that current allowance levels are not adequate to achieve mandated Ao goals.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Pre-Acquisition Reliability Requirements, H-60 Helicopter, Spares

AN ARMY RESERVE MANPOWER PLANNING MODEL

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Because of the expected shortages in its Active Guard and Reserve (AGR) program, the Army Reserve is considering two manpower policy changes. One is the use of Position Vacancy Promotions (PVP) and the other is to allow more officers to serve beyond 20 years of Active Federal Service (AFS). To evaluate the impact of these policy changes, either individually or in combination, on alleviating the shortages, this thesis develops the Army Reserve Manpower Planning model (ARMP). ARMP is an optimization model that determines the annual numbers of accessions, promotions, and separations that best meet the authorized inventory targets. Results from ARMP suggests that a combination of extension of the AFS requirement and allowing PVP can nearly eliminate the shortage in the near future if implemented immediately. ARMP is also useful for managing the AGR officer force.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training, Modeling and Simulation

KEYWORDS: Manpower Planning, Personnel, Optimization, Army Reserve, Active Guard and Reserve

COST-ATTRIBUTE ANALYSIS OF RESTRUCTURING H-60R/S FLEET REPLACEMENT SQUADRONS

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The U.S. Navy helicopter community will soon experience an unprecedented transformation; one that will see a massive shift in the identity of the community and in its fleet operations. In accordance with the Helicopter Master Plan (HMP), two new airframes, the SH-60R and CH-60S, will replace the existing helicopter inventory. This thesis develops the optimal way to structure the Fleet Replacement Squadrons (FRSs), specifying the location of the various FRSs and other training necessities. Four organizational options for restructuring the FRSs are considered: two separate airframe specific FRSs per coast, one combined FRS per coast, one FRS per airframe, and one single site combined FRS. Two different training plans are considered with each option. These training plans will consider whether or not to consolidate those portions of the syllabus common to both airframes. Training, maintenance, and support cost data are determined through the use of VAMOSC data and historical annual training requirements. A thorough attribute analysis of the different alternatives is performed. Using standard economic analysis techniques, multi-attribute decision theory is applied to enable a commander to choose the best option for FRS restructuring. When cost attributes are varied, the best alternative is to have two separate FRSs in NAS North Island, and two separate FRSs in NAS Jacksonville/Mayport.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Manpower, Personnel, and Training

KEYWORDS: Helicopter Master Plan, CH-60S, SH-60R, Cost-Benefit Analysis, Flight Training, Additive Weighting and Scaling Model

AN ANALYSIS OF THE INFLUENCE OF SIGNALS INTELLIGENCE THROUGH WARGAMING

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Signals intelligence (SIGINT), information derived from the monitoring, interception, decryption and evaluation of an adversary's electronic communications, has long been viewed as a significant factor in modern warfare. However, relatively little research has been conducted to quantify the influence of SIGINT in war. The purpose of this thesis is to investigate and quantify the influence of SIGINT in warfare by developing an interactive wargame based on the McCue simulation of the U-boat War in the Atlantic. The research comprises two phases. Phase one consists of constructing an interactive wargame version of McCue's simulation. In the wargame, a human player directs convoys across a chessboard representation of the North Atlantic while the computer controls the movement of the U-boats and tabulates the number of U-boat attack-days. Phase one tests how well the wargame models reality using historical data. The second phase of research consists of experimenting within the wargame to explore the effects of varying levels of SIGINT. Each iteration of the wargame, reflecting one of four possible SIGINT conditions, is repeated to derive statistics about the influence of signals intelligence. The results show about a twenty-five percent net change in the number of attack-days for the side utilizing SIGINT.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Java, Modeling and Simulation, Signals Intelligence (SIGINT), Wargaming

SCHEDULING AND DISTRIBUTING INTRA-THEATRE WARTIME POL REQUIREMENTS

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The Commander-in-Chief, United States Pacific Command (USCINCPAC) Joint Petroleum Office (JPO) oversees the storage and distribution of all petroleum products in the Pacific Theater. JPO planners use the decision support system described in this thesis to help determine if intra-theater wartime petroleum requirements can be satisfied for simulated or operational scenarios. Prior to the work presented in this thesis, JPO performed such analyses manually. The system uses optimization models to produce delivery plans and dispatch schedules for daily shipments of three fuel types via five different transportation modes (pipelines, tankers, barges, railcars, and trucks) amongst fifteen Defense Fuel Support Points (DFSPs). The system uses a spreadsheet interface to import data and to report results, such as fuel inventories and shortages across the distribution network, in tabular and graphical form. Dispatch schedules produced by the system provide detailed schedules for individual transportation assets and test the capacity assumptions employed in the delivery planning model. The USCINCPAC JPO used this system during two recent exercises, simulating wartime operating conditions and environment at the command level; for both exercises the system enabled JPO planners to perform rapid assessments of intra-theater fuel distribution capabilities and quickly validate the feasibility of intra-theater fuel distribution alternatives.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Petroleum Distribution Planning, Linear Programming, Integer Programming, Optimization

FUNDING SITE CLEANUP AT CLOSING ARMY INSTALLATIONS: AN INTEGER LINEAR PROGRAMMING APPROACH

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Since 1988, the United States Army has closed 112 and has completed or will soon complete realignment of another 27 of its domestic installations. The Army estimates the total cost (between 1988 and 2001) of these closures and realignments to be $5.3 billion, of which about $2.3 billion (43%) is associated with environmental cleanup. Beyond 2001, the Army expects to spend an additional $1.09 billion to complete cleanup and continue restoration. The Army Base Realignment and Closure Office (BRACO) is currently funding environmental cleanup at 649 sites on 39 current and former Army installations. BRACO's environmental restoration budget from 2001 to 2007 to support cleanup at these installations (totaling over $620 million) is not sufficient to support each installation's requirement for those years. Considering environmental policies and yearly funding requests from 2001 to 2015 for each site, this thesis develops optimization models and a spreadsheet interface to help BRACO allocate its budget. Model results prescribe either funding each site as requested or delaying cleanup by one to five years. Extensive model use helped BRACO analyze alternate yearly budgets, suggest alternate site funding, and determine site funding for 2001 to 2007.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Integer Linear Program, Optimization, Environmental Cleanup, Budget Allocation, BRAC

ASSESSING THE UTILITY OF AN EVENT-STEP ASMD MODEL BY ANALYSIS OF SURFACE COMBATANT SHARED SELF-DEFENSE

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Anti-ship cruise missiles (ASCMs) are increasing in quantity, capability, and availability throughout the world, posing a significant threat to United States naval forces operating in littoral waters. The improving performance and growing availability of ASCMs makes a persuasive argument for the U.S. Navy to aggressively expand surface combatant defense systems, and perform periodic reviews of existing defensive tactics to ensure effective employment of new combat systems. To guide decision makers in both of these areas, simulation and modeling tools are frequently applied. This thesis assesses an event-step Anti-Ship Missile Defense (ASMD) model through the evaluation of two new hardkill weapon systems, the evolved Seasparrow Missile (ESSM) and an improved Rolling Airframe Missile (RAM). The performance of both systems is evaluated within the context of a single-ship and a multi-ship formation responding to ASCM attacks. The goal of this thesis is threefold, namely to assess the effectiveness of additional anti-ship missile defense systems and identify any tactical insights derived from the modeling results of the multi-ship formation. Following these employments of the model, an evaluation is made regarding the use of the ASMD model as a tool for the tactical commander.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Event-Step ASMO Model, Anti-Ship Cruise Missiles, Surface Combatant Defense Systems

DEVELOPING A PROCESS FOR THE DERIVATION OF THE PROBABILITY OF NEGATION FOR THEATER BALLISTIC MISSILE DEFENSE

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Currently there is some ambiguity about the probability of negation in the current literature of Theater Ballistic Missile Defense. The current literature specifies a probability of negation in defense of either a critical asset or a defended area. What needs to be determined is the probability of negation required per target to ensure that the point target or area is properly defended against a raid. This thesis develops a process to determine the probability of negation per target for Theater Ballistic Missile Defense. The aforementioned process led to the creation of a simple but useful tool implemented in Microsoft Excel. The tool allows for a variety of inputs to include multiple layers, varying levels of confidence, varying probabilities of engagement support, and a variable number of shots per salvo per layer. It is available at http://web.nps.navy.mil/~buttrey/Software.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Probability of Negation, Targeting, Negation per Target, Theater Ballistic Missile Defense

STOCHASTIC SIMULATION OF A COMMANDER'S DECISION CYCLE (SSIM CODE)

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This thesis develops a stochastic representation of a tactical commander's decision cycle and applies the model within the high-resolution combat simulation: Combined Arms Analysis Tool for the 21st Century (Combat XXI). Combat XXI is a Joint Army-Marine Corps effort to replace the Combined Arms and Support Evaluation Model (CASTFOREM)-a legacy combat simulation. Combat XXI is a non-interactive, high-resolution, analytical combat simulation focused on tactical combat. Combat XXI is being developed by the U.S. Army TRADOC Analysis Center-White Sands Missile Range (TRAC-WSMR) and the Marine Corps Combat Development Command (MCCDC). Combat XXI models land and amphibious warfare for applications in the research, development and acquisition, and the advanced concepts requirements domains. Stochastic decision-making enhances Command and Control (C2) decision processes in Combat XXI. The stochastic simulation of a commander's decision cycle (SSIM CODE) addresses variability in decision-making due to uncertainty, chance and the commander's attributes. A Bayesian Network representation of a conditional probability model for a commander's decision cycle is implemented in SSIM CODE. This thesis develops, applies and evaluates the effectiveness of SSIM CODE.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Command, Control and Communications, Battlespace Environments

KEYWORDS: Combat Models, Simulation, Decision-Making, Decision Cycle

A COMPREHENSIVE STATISTICAL ANALYSIS OF SUBSTANCE ABUSE PATTERNS AND TRENDS WITHIN THE UNITED STATES ARMY

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The United States Army's Center for Substance Abuse Programs relies on a broad based approach to combat substance abuse. Certain factors, however, have been associated with a soldier's involvement with substance abuse. They include age, race, gender, military occupation specialty, and rank.

A statistical analysis of recent drug and alcohol use/abuse patterns would permit the Army to target services and programs toward those most at risk for developing substance abuse related problems. Additionally, a model that could profile the typical enrollee into the Army's Substance Abuse Program, ASAP, would be a valuable predictive mechanism for future abuse trends within the Army.

This study supports the United States Army's Center for Substance Abuse Programs' efforts to improve the identification of those most at risk for substance abuse. This study provides a detailed statistical analysis on current substance abuse patterns within the United States Army and civilian society, and presents a mathematical model of ASAP enrollments.

DoD KEY TECHNOLOGY AREAS: Biomedical, Manpower, Personnel, and Training

KEYWORDS: Substance Abuse, Alcoholism, Drug Abuse, DUI, DWI, United States Army, Cluster Analysis, Time Series

ANALYSIS, DESIGN, IMPLEMENTATION AND EVALUATION OF GRAPHICAL DESIGN TOOL TO DEVELOP DISCRETE EVENT SIMULATION MODELS USING EVENT GRAPHS AND SIMKIT

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Discrete Event Simulation (DES) is one of the most widely used methodologies for Operations Research (OR) modeling and analysis. However, designing and implementing DES can be a time-consuming and error-prone task. This thesis designed, implemented and evaluated a tool, the Event Graph Graphical Design Tool (EGGDT), to help OR analysts in the design, implementation, and maintenance of DES reducing the development and debugging times.

The Unified Modeling Language was used to document the development of the EGGDT, which was programmed in Java using J2D and Swing. Human Factors techniques were employed to help in the design process and to evaluate the final prototype of the EGGDT.

During the design process, two formative experiments were performed to evaluate the Graphical User Interface design decisions. A final summative experiment was done to test if the potential users consider the tool a useful means to develop OR simulations. Participants of the experiments agreed that tools like the EGGDT are an essential instrument when developing simulations.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Discrete Event Simulation, Event Graph Graphical Design Tool, Graphical Design Tool

CASE STUDY IN MODELING AND SIMULATION VALIDATION METHODOLOGY

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The military develops and uses simulations to analyze nearly every aspect of defense. How accurate are these simulations and to what extent do they produce dependable results? This thesis explores practical validation techniques from the bottom-up in the form of a case study. The platform used is the theater ballistic missile defense aspects of the new simulation Wargame 2000. This research will be particularly useful when combined with further case studies to provide a global perspective to validating large-scale military models and simulations. Wargame 2000 is compared to a baseline existing model, EADSIM.

The focus here is not to validate or invalidate Wargame 2000 but to develop real, usable tools to compare a simulation's results against baseline results. This work focuses on measures of effectiveness characteristic of missile defense. Data collection includes defense battery search, engagement and intercept times for a variety of threats but does not include tracking information. Results from each model are compared using both graphical methods and inferential statistics. Insight is provided into developmental and data production issues which can make the validation process more effective and meaningful.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Validation, Simulation Validation, VV&A, Model-Test-Model, Wargame 2000, EADSIM, Theater Ballistic Missile Defense

ANALYSIS OF ROUGH SURFACE LIGHTING BEHAVIORS WITH OPEN GL

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In the physical world, humans gather valuable information about objects through their sight. Information on shape, feel and composition are seen long before the object is touched. This information is generated by light reflecting off the surface of objects. Despite the advancement of computer graphics due to increased hardware rendering capacity, the fundamental equations, which draw three-dimensional scenes, lack the ability to truly model realistic objects. Whether it is smooth like highly polished metal or rough like the shag of a carpet, it is the reflection of light that tells humans what a surface feels like. The attempt taken in this thesis to implicitly model the roughness of textured surfaces through examination of an explicit model rendered with the OpenGL lighting equation. This approach has the potential to successfully increase the realism of computer graphics without increasing polygon count required for explicit surface generation. Through simulation of an explicitly constructed rough surface followed by the analysis of the behavior of its reflected light, the initial behaviors of textured surface reflections are identified. While these behaviors are not enough to create corrections to the OpenGL lighting equation, they lay the foundation for further development.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human-Systems Interface

KEYWORDS: Open GL, Lighting Behaviors

EFFECTIVENESS OF NAVAL SURFACE FIRE SUPPORT TO THE ARMY BRIGADE COMMANDER IN A LITTORAL CAMPAIGN

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Since the end of the Cold War, the Army has been engaged in an unprecedented number of joint contingency operations that run the gamut from humanitarian efforts in Cuba and Haiti to peace-enforcing and peace-keeping in Bosnia to full scale war in Southwest Asia. These operations, the result of an increasingly complex international security environment, hint at future missions involving American forces aimed at protecting U.S. interests worldwide.

To engage and defeat future threats to our national security, the Army must transform itself into a more strategically responsive, lethal force. The Army is faced with the challenge of lightening the force while simultaneously increasing its survivability and lethality. Reach-back technologies from sea, air, and space can provide Army units with added lethality without encumbering them further.

This thesis analyzes the ability of the Army to effectively utilize Naval Surface Fire Support (NSFS) to provide indirect fire in support of brigade-sized units. The Fire Support Simulation Tool (FSST) takes the capabilities and limitations of weapon systems being studied and simulates their employment in the context of a well-defined scenario for analysis. The output from the simulation provides the input for the analysis of NSFS.

By comparing the utility of several well-constructed courses of action, the FSST can help decision-makers determine the effectiveness of NSFS within the context of the scenario being considered. The results of this analysis determined that although a myriad of issues such as training, mistrust, and synchronization must be addressed to make reach-back fires successful, there is strong quantitative and analytical evidence to support the effectiveness of NSFS to an Army Brigade commander engaged in a littoral campaign.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control, and Communications, Computing and Software, Conventional Weapons, Modeling and Simulation

KEYWORDS: NSFS, Simulation, Java, FCS, IBCT, Artillery, DD21, DD-21, Paladin, Crusader

REDUCING NON-MONOTONICITIES IN COMBAT MODELS

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Non-monotonic behavior in combat models is an important topic to those using the output of such models as a basis for decision making. These decisions can be complicated by non-monotonic behavior in the combat models. This paper examines the Dewar model which exhibits non-monotonic behavior caused by the chaos inherent in its structure. Previous papers have examined only small subsets of this 18 dimensional combat model. The combinatorial possibilities of main effects and interactions among the 18 dimensions are too great to examine en masse. Consequently, there are three goals. First, systematically explore the Dewar model for additional non-monotonic behavior. Second, determine the effect of stochastic modeling on the non-monotonic behavior of the Dewar model response surface. Third, develop a method for measuring non-monotonicity in the response surface generated by the model. Latin Hypercube Sampling discovers non-monotonicity across broad regions of the model's phase space, and in multiple measures of effectiveness. Stochastic perturbation of model parameters has a dramatic effect on the non-monotonicity of the response surface. Stochastic perturbation can both reduce and exacerbate the non-monotonic behavior of the response surface. If done properly, stochastic modeling can significantly improve the interpretability of the response surface.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Combat Models, Non-Monotonic Behavior, Stochastic Modeling

SCHEDULING THE RECRUITING AND MOS TRAINING OF ENLISTED MARINES

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Non-infantry enlisted Marines progress through Recruit Training, basic infantry training at Marine Combat Training (MCT), and Military Occupational Specialty (MOS) training before finally reporting to their first unit for duty. These Marines are the focus of this thesis. In fiscal year 1998, new recruits spent over 2,700 Marine-years (wait time) in an unproductive status while waiting on their next training schools to convene. Marine Corps manpower planners believe this level of wait time is unacceptable. This thesis develops two integer linear programs to plan recruiting and MOS school seat scheduling with the primary objective to minimize the time non-infantry enlisted Marines wait for MOS training. The first model, the Long-term Recruiting and MOS School Scheduler (LRAMS) plans both recruiting and MOS training to help MOS training schools' develop their training schedules two years prior to execution. The second model, the Short-term Adjusted Recruiting Model (STAR) is used after the MOS training school schedules are published to develop a coordinated recruiting schedule. Results indicate that wait time can be reduced significantly. For fiscal year 2001, LRAMS results provide a wait time of only 160 Marine-years.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Manpower, Personnel and Training

KEYWORDS: Integer Optimization, Scheduling, Resource Constrained Problems

THE BOOST PROGRAM AND ITS EFFECT ON RETENTION AND PERFORMANCE
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This thesis is an analysis to determine if fleet input (Track I) compared with civilian input (Track II) personnel into the Broadened Opportunity for Officer Selection and Training (BOOST) program is related to the retention and performance of a Navy commissioned officer. The data focuses on BOOST classes, 1981-1992, to measure fleet performance and retention. Prior-enlisted officer (Track I) BOOST graduates obtain a subspecialty, receive graduate education, and enter the Lieutenant Commander promotion board at statistically significant higher rates than their civilian (Track II) counterparts. It is hypothesized that candidates with a "prior service" background have more knowledge, commitment and overall understanding of the military that will help them succeed as officers.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: BOOST, Officer Programs, Prior Service, Retention

AN IMPROVED HEURISTIC FOR TOMAHAWK LAND-ATTACK PREDESIGNATION, ENHANCED TO ACCOMMODATE MANUAL PLANNING, AND VALIDATED WITH FLEET EXERCISE DATA
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The Tomahawk Land-Attack Missile (TLAM) has become the weapon of choice for strategic and tactical land-attack warfare. Tomahawk provides long-range, reliable, unmanned land-attack capability with pinpoint accuracy. Strike planning is the process by which Tomahawks are assigned to firing units for target prosecution. Currently, the Tomahawk Strike Coordinator (TSC) performs strike planning by hand. In order to improve strike planning, a fast heuristic has been developed to allocate TLAM tasks-the target to be attacked and the time period in which the missile must be fired-to firing units in multiple battle groups and launch areas over successive time periods. Until now, the heuristic with just 12 simulated scenarios was tested. To determine the heuristic's performance vis-à-vis current manual strike planning, heuristic solutions to TSC allocations from two U.S. Third Fleet exercises-TEXAS THUNDER 00-6 and RIMPAC 00-3 are compared. The heuristic produces a more efficient allocation than the TSC for every one of 13 exercise salvos. The heuristic to accommodate manual planning is augmented, with two computer-assisted alternatives - task-to-firing unit and firing unit-to-task - that help the TSC discover and address subtle details that influence mission success, and apply expert human judgment regarding practical considerations.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Strike Planning, Tomahawk Land-Attack Missile, Tomahawk Strike Coordinator

FINDING THE IMPORTANT FACTORS IN BATTLE OUTCOMES: A STATISTICAL EXPLORATION OF DATA FROM MAJOR BATTLES

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This study explores important factors in battle outcomes through a statistical analysis of data from major historical battles. The data set of CDB90FT has been made available and documented by the Center for Army Analysis (CAA). The quality of the historical data is good. There are 660 battles listed in the data set containing over 140 numerical features for each battle. The earliest battle in the data set is the Netherlands' War of Independence in 1600, while the last one is from the Israel-Lebanon War in 1982. The data set contains many interesting facts on the battles including the initial strengths, the total strengths, the number of casualties, the lengths of the front lines, terrain features, command capability of leaders, weather conditions, etc. The approach is to use the data set as the basis for an objective and scientific comprehensive analysis, seeking patterns, trends, and relationships in combat. After making campaign-wise grouping and analysis, it is found that the Force Ratio is a valid estimator of the battle outcome. In addition, the Casualty Rate has declined steadily over the past four centuries while Dispersion has increased.

DoD KEY TECHNOLOGY AREA: Other (History)

KEYWORDS: Dispersion, Daily Casualty Rate, Force Ratio