MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

MASTER OF SCIENCE IN OPERATIONS RESEARCH

A HEURISTIC PROCEDURE TO AGGREGATE CONTAINERS ONTO PALLETS AND PLAN THE LOADING OF PALLETS INTO TRUCKS

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A heuristic procedure is presented which aggregates containers of multiple products onto pallets and then plans the loading of these pallets into trucks. The efficient loading of products onto pallets and pallets into trucks is an economic fundamental. In 1993 the value of products shipped by truck in the United States exceeded 4.6 trillion dollars or about 75.6 percent of gross domestic product. Industry sources estimate that 98% of all manufactured products are transported on pallets. The heuristic provides feasible solutions to the pallet and truck loading problem in real time. The method considers "real-world" criteria new to the literature, such as stacking compatibility among product containers and axle weight limits for trailers. The procedure is demonstrated with actual examples from the Defense Logistic Agency (DLA) and a commercial company.

GENERALIZED OPTIMIZED MODELING FOR DEFENSE CAPITAL PLANNING AND EQUIPMENT REPLACEMENT

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Recurring issues for Navy and DoD analyst are decisions on the upgrade, purchase, and retirement of equipment with high capital cost and long useful life. Since the PHOENIX model was developed in the late eighties a number of these addressing different equipment procurement and modernization problems have been written at the Naval Postgraduate School. Those models have a common thread of purpose, data, and methods that suggest the possibility of building a common model subsuming those previous efforts.

The model developed is a mixed-integer linear program written in GAMS, and its most appealing characteristic is the spreadsheet application that allows the user to enter data, solve the model, analyze its output, enter user feedback in the process of finding a new solution, and also to manage a collection of candidate solutions.

With this approach difficulties are hidden from the user who interacts only with the spreadsheet and does not have to build his own model. The combination of a generic model and the visual programming capability of Excel provides the user with a tool to accomplish more complete, complex and sophisticated analysis.

THE EFFECT OF GENDER ON ATTRITION AT THE DEFENSE LANGUAGE INSTITUTE FOREIGN LANGUAGE CENTER

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Second Reader: Stephen M. Payne, Defense Language Institute

The Defense language Institute Foreign Language Center (DLIFLC), located at the Presidio of Monterey, California, provides language training for Department of Defense military and civilian personnel. The Institute trains approximately 2,500 students annually, of which approximately 26 percent are female. Student attrition is a costly feature of this training program. Females experience roughly a 7 percent higher rate of attrition than males at DLIFLC. The Institute is interested in knowing whether this difference indicates a gender bias, or whether it can be explained by other factors. This study investigates this question. Specifically, data on FY-95 DLIFLC students are examined to

determine factors which have a significant impact on attrition, with particular emphasis on the effects of gender. Such information is useful to the Institute for internal quality assurance efforts as well as part of potential cost saving measures.

A METHODOLOGY FOR UPDATING THE NAVY'S LOGISTICS FACTORS FILE

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This thesis develops a methodology for updating the Navy's Logistics Factors File, which has been neglected in recent years and requires updating. This study is limited to Repair Parts (Class IX of the Department of Defense Supply Class Codes) for the following four classes of ships: CVN-68 (Nimitz class) Aircraft Carriers, CG-47 (Ticonderoga class) Guided Missile Cruisers, DD-963 (Spruance class) Destroyers, and FFG-7 (Oliver Hazard Perry class) Guided Missile Frigates.

The current Logistics Factors File structure includes a single data entry in pounds per unit per day to describe the sustainment requirements of these units for all of the supply classes and their respective subclasses. For Repair Parts, these values are severely understated when compared to contemporary data. These "pounds per unit per day" random variables have heavily skewed distributions. These distributions can be fitted with mixtures of standard probability distributions, and it seems wise to recommend that associated variability information be included either directly in the Logistics Factors File, or in a readily available companion source.

OPTIMIZING THE MODERNIZATION OF EASTERN EUROPEAN FORCES

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Many Eastern European countries desire a method to evaluate the capability and cost of their military forces. In 1995 the Program Analysis and Evaluation branch of the Office of the Secretary of Defense (OSD PA&E) provided a solution: the Defense Resources Management Model (DRMM). The DRMM is a database system that contains detailed report writing, allowing a nation's military to be described by: how its forces are organized and equipped; how it staffs its forces; how it scales its peacetime training rates; and how it practices budgeting and accounting. We present a multi-objective linear program extension to the DRMM that suggests optimal yearly unit levels, activity, manning, equipment, and war reserve materiel levels. Two objectives are used in the analysis: (1) We find the minimum budget required to maintain a given capability level, and (2) We find the maximum capability within an annual budget. Possible uses of the linear programming extension are demonstrated using a hypothetical but realistic Eastern European force supplied by OSD PA&E. Results show the ability to maintain current capability but reduce annual spending by up to 30 percent. Other results show how capability can be increased nearly 50 percent over a five-year time horizon by increasing annual budget levels ten percent above their current levels.

EVALUATING OPERATIONAL MANEUVER IN A COMPUTER-AIDED EXERCISE

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Second Reader: George Connor, Department of Operations Research

The development of proficient Joint Staffs at the Joint Task Force level is receiving increased emphasis. One of the primary training tools available is the use of computer-aided exercises. In utilizing these devices for training Joint Task Force Staffs, many observations can be made over the course of the exercise which aid in assessing readiness. The primary document used to focus the training and assessment effort is the Universal Joint Task List. The list provides both the staff and evaluators with a common document outlining critical events and activities which require successful accomplishment. the document is organized in a manner which defines activities associated with the many functional areas of staff activity including logistics, intelligence, force protection, and operational firepower planning.

It is the purpose of this thesis to provide a methodology for objectively assessing the staff's ability to conduct operational maneuver. Experimental runs using the Joint Theater Level Simulation demonstrate how critical events and command control decisions affect the tempo of battle and produce data elements which are useful in developing measures of performance for operational maneuver.

TRADEOFF ANALYSIS MODEL FOR ARSENAL SHIP SURVIVABILITY AND SUSTAINABILITY

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Master of Science in Operations Research-September 1996
and
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Second Reader: Charles N. Calvano, Department of Mechanical Engineering

The arsenal ship program is unique and requires examining the possible features of a paradigm shift in ship design. This thesis presents a user-friendly model with which a decision maker can perform tradeoff analyses between adding specific systems and technologies to the arsenal ship or adding the escort services of combatant ships. The goal of the model is to produce configuration alternatives with high arsenal ship survivability subject to a budget constraint. The model also examines operational logistics by predicting the sustainability of forces with specified arsenal ship configurations. As some inputs are necessarily speculative at this stage, the model is formatted parametrically to facilitate easy updating. A balanced arsenal ship design incorporating point defense, stealth, and hardening is the most attractive choice for littoral operations when life cycle costs are considered. The naval component must also be balanced, reinforcing the notion that stealth and staying power are important in an arsenal ship task force containing DDG-51s and SC-21s.

SUITABILITY OF BOX-JENKINS MODELING FOR NAVY REPAIR PARTS

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A basic function in the proper management of repair part inventories is the forecasting of future demand. The Navy maintains a database of univariate demand data for its repair part inventories using a quarterly time interval. Historically, Navy repair part demand forecasting has been done using the exponential smoothing procedure. This method is a simple and robust means of forecasting, however it does not make use of any characteristics of the entire time series such as trend, cycles, presence of outliers, or demand clustering.

This research begins by developing several simple, robust, and dimensionless time series features. These features are used to predict the suitability of Box-Jenkins (ARIMA) modeling. The ARIMA process is a powerful time series modeling and forecasting technique which possesses flexibility for the inclusion of many time series characteristics. This research project develops a predictive model of ARIMA suitability using both classical regression and a modern expert-system statistical package, ModelQuest. A computationally simple means is presented for determining which time series may benefit from the Box-Jenkins methodology. Using ARIMA modeling for time series that show significant benefit will provide a more accurate demand forecast and benefit inventory management.

OPTIMALLY SCHEDULING THEATER MISSILE DEFENSE PROCUREMENT

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The Ballistic Missile Defense organization (BMDO), overseas the procurement of Theater Missile Defense (TMD) systems. Anticipated expenditures for TMD systems are roughly 15 billion dollars (including money already spent) by 2002, and 31 billion dollars by 2010. A Cost and Operational Effectiveness Analysis provides guidance on the most cost effective mix of TMD inventories to procure for defense against both theater ballistic missiles and cruise missiles, but history indicates that cost growth and schedule growth are likely. We develop a mixed integer linear programming model to help BMDO plan resource allocation for procurement of TMD systems. The model selects an optimal procurement strategy from user-supplied alternatives for each TMD system that most closely satisfies yearly budget levels and system fielding requirements. Alternatives are derived from existing procurement schedules by stretching or contracting the schedule and applying basic learning theory. We develop a tradeoff between budget limits and operational requirements that is tied to the cost of exceeding the budget. Using a baseline of existing procurement schedules, we analyze the effects of imposed operational requirements on the budget, and demonstrate how the added flexibility of alternate procurement schedules improves results.

AN EVALUATION OF AN ALTERNATIVE SUPPLY SYSTEM TO SUPPORT THE REPUBLIC OF CHINA'S ARMY

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This study examines the effect of a Point of Sales (POS) type of military supply system on the readiness of a typical Republic of China infantry battalion. The study compares the current system against the POS-like system. Chapter II is a background of the current supply system and the alternative system studied in the thesis. Chapter III develops a stochastic model to generate parts availability probability values for the support of three types of equipment assigned to a battalion. Chapter IV uses these probabilities to populate a decision tree for the determination of which system will increase the readiness of the battalion. A GAMS Program is used in Chapter III to generate the probabilities for support and a Decision Support Program (Data) is used to develop the decision tree and for the analysis of the results.

The results were that without considerations of cost savings that may be realized in such a system the POS system produced a small increase in the readiness of the battalion. Chapter V presents the author's conclusions and recommendations for a more detailed and rigorous study of the proposed alternative supply system.

DATA AND MODEL MANAGEMENT FOR THE JOINT WARFARE EXPERIMENTAL PROTOTYPE

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This thesis describes a new data management design for the *Joint Warfare Analysis Experimental Prototype (JWAEP)*, a joint theater level, low resolution stochastic simulation developed at the Naval Postgraduate School. The design calls for (1) a 32 bit Windows program to access the JWAEP data which is stored in a SQL database server, (2) direct output of the database information into the plain text input files on the Unix host machine, and (3) remote execution of the JWAEP model via the network.

The viability of this design is demonstrated in the JWAEP Management Information System (JMIS) prototype program. JMIS is shown to be capable of achieving the stated design features; however, due to the size of the JWAEP database, it has not provided a full implementation of each of the design features. In addition, this thesis discusses the issues that have to be considered to maintain JMIS in synchronization with future developments in JWAEP.

TRADEOFF ANALYSIS MODEL FOR ARSENAL SHIP SURVIVABILITY AND SUSTAINABILITY

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The arsenal ship program is unique and requires examining the possible features of a paradigm shift in ship design. This thesis presents a user-friendly model with which a decision maker can perform tradeoff analyses between adding specific systems and technologies to the arsenal ship or adding the escort services of combatant ships. The goal of the model is to produce configuration alternatives with high arsenal ship survivability subject to a budget constraint. The

model also examines operational logistics by predicting the sustainability of forces with specified arsenal ship configurations. As some inputs are necessarily speculative at this state, the model is formatted parametrically to facilitate easy updating. A balanced arsenal ship design incorporating point defense, stealth, and hardening is the most attractive choice for littoral operations when life cycle costs are considered. The naval component must also be balanced, reinforcing the notion that stealth and staying power are important in an arsenal ship task force containing DDG-51s and SC-21s

ANALYZING AMPHIBIOUS LOGISTICS CAPABILITIES IN THE JOINT THEATER LEVEL SIMULATION (JTLS)

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One of the primary tools available to a Unified Commander-in-Chief (CINC) for training his staffs in execution of their joint plans is a command post exercise supported by a computer simulation. This is commonly referred to as a Computer Aided Exercise (CAX). The computer simulation used for this thesis is the Joint Theater Level Simulation. Currently, the after-action reviews (AARs) are mostly subjective in nature with very little quantitative analysis. The objective of this thesis is to develop a methodology for quantitatively evaluating the data produced by the computer simulation and presenting this analysis graphically. The methodology is based on the Universal Joint Task List which is a comprehensive listing of all joint tasks pertaining to the Armed Forces of the United States. These joint tasks provide the critical events that are analyzed during the CAX. The graphs display a causal audit trail for the critical events of the CAX. The focus of this thesis is on Strategic Task Four, Theater Logistics, with specific analysis of amphibious logistics operations.

A TIME SERIES ANALYSIS OF U.S. ARMY ENLISTED FORCE LOSS RATES

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The analysis and prediction of personnel loss behavior is critical to effective manpower planning and to the U.S. Army's Enlisted Personnel Strength Management System (EPSMS). In support of efforts to modernize the EPSMS, this thesis examines the method by which the Enlisted Loss Inventory Model (ELIM) analyzes loss rates and forecasts them into the future.

Time series analysis techniques seek to identify patterns in data and forecast them into the future via time based extrapolations. Four such methods were used to construct loss rate forecasts from data. These methods were the arithmetic mean, exponential smoothing (the current ELIM method), seasonal exponential smoothing and an autoregressive moving average model. Forecasted rates were used to project force strengths which were in fact known. The resulting errors in forecasted strength were analyzed, compared and contrasted with respect to the methods.

Error analysis revealed no significant performance differences between the methods. Hence, the simplest methods (mean and exponential smoothing) may be viewed as more economical and preferred.

A MARKOV MODEL FOR PARAMETRIC SENSITIVITY ANALYSIS OF *CRUSADER* EFFECTIVENESS

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This thesis presents a Markov model for analyzing the sensitivity of *Crusader* effectiveness to parametric changes in *Crusader* capabilities. *Crusader* activities are represented as finite-state, discrete-time Markov chains. A series of supporting models for some of the Markov model parameters provide for the desired sensitivity analysis on specified engineering characteristics of a *Crusader.* A Microsoft *Excel V7. 0* spreadsheet serves as the user interface, computational tool for the models. A Microsoft *Visual Basic* program manipulates the transition probability matrices then returns the results of the Markov model. Available measures of effectiveness include the time until *Crusaders* are killed by enemy counterfire and the number of fire missions executed and lost by *Crusaders. A* demonstration of the spreadsheet implementation shows the models can be used for the desired sensitivity analysis. While creating a model for *Crusader* was the motivation for this thesis, the model can be used to conduct similar analysis on current or competing field artillery systems.

OPTIMAL FLEET MODERNIZATION MODEL FOR THE U.S. NAVY'S COMBAT LOGISTICS SUPPORT HELICOPTER

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As the United States Navy's primary helicopter for combat logistics support, the Boeing H-46D "Sea Knight" helicopter has served as a multi-mission platform for vertical replenishment at sea, vertical onboard delivery, and search and rescue operations. The current fleet of H-46Ds is nearing the end of its service life with no definitive plans for replacement. To aid the Navy in its replacement decision, this thesis develops an optimization model useful in evaluating different replacement alternatives. To demonstrate its effectiveness, the model is implemented in the General Algebraic Modeling System (GAMS) and is used to evaluate several alternatives such as conducting a service life extension program, procuring new helicopters, leasing, and awaiting the transfer to the Navy of the H-46E helicopter from the U.S. Marines in FY 2002.

SIMULATION OF A RADAR DETECTION MODEL USING THE NPS PLATFORM FOUNDATION

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The extensive cost to thoroughly compare new radar sensor systems is a problem in today's military. Due to the shrinking defense budget, the opportunity to replace dated sensor systems, with technologically advanced systems, seldom arises. Current funding levels no longer support long term evaluations of sensor system performance. The development of new methods to measure system performance is crucial in determining the best sensor system among many alternatives. Computer simulation is one method of conducting additional trials to characterize sensor system performance. Computer simulation can aid decision makers in selecting the sensor system that best meets the needs of the current military force structure. The cost of simulation modeling is considerably less than repeated testing of the

real sensor system. This research investigates the feasibility of developing a computer simulation of a radar sensor system. The scope of the research includes computer modeling of the detection process and an evaluation of model output. This simulation model is an initial step to emphasize the power of computer simulation.

A JOINT CAMPAIGN ANALYSIS APPROACH TO ANTISUBMARINE WARFARE USING A CIRCULATION MODEL TEMPLATE
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To enhance insight into a war at sea, a general, aggregated and highly flexible model of the ASW campaign is offered. This thesis provides a simple and usable circulation model template. The generality and simplicity of the model allows for "jointization" of an ASW campaign by allowing the user to utilize other resources to define the force mix. The model is designed, first and foremost, to examine the change in the marginal effectiveness of friendly ASW forces due to changes in force level, mix, effectiveness, and employment strategies. The model is keyed to the interaction of a threat submarine with friendly ASW forces and merchant or military shipping. Specific features of the model provide for four unique attack regimes. The in port and operational regimes control friendly attacks on a daily basis while the outbound and inbound regimes control barriers by events. The campaign model is a deliverable product programmed using *Borland® Delphi™* for use in *Microsoft® Windows.®*

BUDGETING FOR ENVIRONMENTAL CLEAN-UP OF ARMY BASES
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The United States Army obtained congressional approval in 1995 to close or realign 40 installations. These actions create a unique opportunity for the civilian communities surrounding the installations to reuse them to satisfy commercial or community needs. However, future reuse can be impeded by the need for environmental clean-up, which is an expensive business. The current clean-up cost estimate for 32 of the 40 installations is $1 billion from 1996 to 2001. This thesis develops an optimization model with a spreadsheet interface to help plan distribution of yearly environmental clean-up budgets. The model picks from supplied alternatives the clean-up level for each area within each installation that provides the greatest benefit for reuse while adhering to yearly budgets. To measure benefit this thesis develops a linear value model that quantifies the qualitative factors that provide benefit to a community. Extensive computational testing using Army and hypothetical data demonstrates how the model can help the Army effectively allocate their budget.

MASTER OF SCIENCE IN OPERATIONS RESEARCH

A METHODOLOGY FOR EVALUATING THE PERFORMANCE OF OPERATIONAL FIREPOWER DURING A COMPUTER-AIDED EXERCISE

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One of the primary tools available to a Joint Commander-in-Chief (CINC) for training his staff on their joint mission essential tasks is a command post exercise (CPX) supported by a computer simulation model. This is commonly referred to as a Computer-Aided Exercise (CAX). Computer-Aided Exercises are an essential part of training a component staff; however, one weakness with these valuable tools lies in the measurement of the level of training received by the players. In most CPXs the players rapidly disperse after the exercise and little quantitative data are captured during the running of the CAX that allows for a quick post exercise analysis. This research presents a methodology for evaluating the performance of joint operational firepower tasks as set forth in the Universal Joint Task List. While demonstrating this methodology for developing quantifiable measures of effectiveness in operational firepower, this thesis also shows how the relationship of operational firepower and operational intelligence can be refined for enhanced firepower effectiveness.

INTEGER PROGRAMMING BASED INVESTMENT TRADE-OFF

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The Department of Defense budget will decline in real terms by 41 percent from 1985 to 1997. Maintaining capable forces within this tightening budget increases the importance of procurement decisions and thereby the need to compare the cost and effectiveness of weapon systems designed for different missions in conjunction with force structure changes. We formulate two mixed integer linear programming models each designed to help determine an optimum procurement strategy from supplied procurement and force structure options. Weapon system procurement options represent different user defined quantities or yearly schedules to obtain desired quantities. Force structure options include changes to the number and location of units (e.g., disestablishing air wings or pre-deploying an army brigade). Each option has a calculated effectiveness measure. The mixed integer linear programs select the options that yield the most effective force while adhering to annual budgets. This thesis demonstrates the mixed integer linear programs using realistic data for Brilliant Anti-Armor Submunition, Sensor Fused Precision Guided Munitions, Longbow Apache Helicopters, and the C-17 in conjunction with changes to force structure. Results indicate no difference in the optimum strategy selected by either of the two mixed integer linear programs which only differ in the option's mathematical effectiveness representation. One uses a more general effectiveness representation but requires substantially more time to obtain an optimal solution. Additionally, we demonstrate how the expected effectiveness reacts to changing budget conditions.

THEATER AIR APPORTIONMENT AND ALLOCATION: APPLICATION OF DYNAMIC ALGORITHMS FOR COMBAT MODELS

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The purpose of this thesis is to design, develop, and demonstrate a decision model to dynamically apportion and allocate air assets in a theater level combat model subject to specified air campaign plan. The methods described are combined into a stand-alone air apportionment / air allocation $(AA)^2$ model.

The model translates the objectives of an air campaign phases into sets of strength categories that are used to value enemy unit capabilities. These strength categories are assigned desired levels by a user that define when a strength has been reduced to an acceptable level. These desired levels apportion friendly air assets between different strength categories based on the objectives the campaign phases. The strength categories are also used to value each potential target. These values are used to allocate sorties to reduce the strength of the potential target to the desired level. The model uses the strength values of potential targets to determine if the objectives of a campaign phase have been satisfied and whether to activate any follow-on phases. A demonstration of the $(AA)^2$ model is included using a two-phase air campaign.

MODELING LIGHT VALVE REPLACEMENTS IN A TRAINING UNIT: THE SPARE DEMAND PROCESS.

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This thesis utilizes data on the time to failure of individual light valves to represent the random process of all failures at a many-valve training unit. This process governs the demand for replacement spares. The light valve replacement model, with finite spares, is based on theoretical results concerning the Poisson tendency for a superposition of renewal processes. Graphical analysis and a simulation verify that the theory can apply under practical circumstances. The model is distinguished by its applicability for use in standard spreadsheets; no specialized statistical features are required.

AEGIS VERTICAL LAUNCH SYSTEM LOADOUT MODEL FOR BALLISTIC MISSILE DEFENSE

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This thesis develops a model to assist in determining the optimal loadouts of surface-to-air missiles (SAM) and anti-ballistic missile missiles (ABM) to combat both an expected number of anti-ship cruise missiles (ASCM) and theater ballistic missiles (TBM). Through simple mathematical modeling using a spreadsheet, the number of SAMs and ABMs are calculated along with the number of ships required to adequately defend a city targeted by ballistic missiles. To validate the information produced by the spreadsheet, a mid-fidelity simulation was constructed using the MODSIM II language. Through the use of Monte Carlo simulation, the program produced "survivability" curves based on the loadouts. Simulation output shows that the spreadsheet recommends loadouts near the optimal survival probabilities for a number of combinations of expected ASCMs and TBMs.

AN ECONOMIC MODEL FOR SEABORNE OIL TRADE

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This thesis aims to provide some insights as to how oil prices and oil flows might vary with the carrying capacity of the tanker fleet as affected by political events. It provides an econometric analysis of tanker freight rates in the modern era and proposes a mathematical (quadratic) programming economic model that links the crude oil market to the supply elasticity of the world oil tanker fleet based on a competitive economy. The economic model can be considered as a version of the Walras-Cassel general-equilibrium system which possesses an economically meaningful equilibrium solution in terms of oil prices, freight rates and the pattern of oil distribution. The implementation of the model is completed using the General Algebraic Modeling System (GAMS). The study concludes with a scenario study showing how the model could be used to examine the importance of South East Asia's sealanes in world seaborne oil trade. The model shows the economic vulnerability of oil importing nations, especially Japan, the United States, and Western Europe, to a possible closure of South East Asian sealanes.

MODELING THE EFFECTS OF LOGISTICS UPON GROUND MANEUVER AND COMBAT

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Second Reader: Samuel Parry, Department of Operations Research

Logistics can substantially affect the directions of warfare campaigns. The types of war material and their flow rates to field units directly impact the campaign outcome. Although many wargaming and combat simulations have been developed, few models implement the detailed effects of logistics flow. This thesis develops a theater level logistics flow model for a Blue force using a forward logistics base that is advancing upon an objective in Red defended territory. The model computes confidence intervals for Blue's short tons of various classes of supply available throughout the campaign. Logistics activity is generated at user defined rates using four periodic and event driven consumption mechanisms: movement, combat, interdiction, and interdiction repair. The model's primary function is receipt, staging, onward movement, and integration for materiel consumed by Blue. The model is implemented in MODSIM, an object-oriented simulation language providing both synchronous and asynchronous events, as well as a rich class of data structures necessary to implement the model. The basic model is replicated to desired confidence and tolerance, with statistics collected for the amounts of the various classes of supply available for the supported units. The model's output includes confidence intervals for the desired measures of effectiveness.

MODELING ATTACK HELICOPTER OPERATIONS IN THEATER LEVEL SIMULATIONS

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This thesis describes an attack helicopter module for the *Joint Warfare Analysis Experimental Prototype (JWAEP)*, a joint theater level, low resolution stochastic simulation developed at the Naval Postgraduate School. The modeling formulations, required data, and assumptions which are required to portray attack helicopter operations in theater level simulations are presented. The focus for the attack module is the representation of attack helicopter units in the conduct of deliberate attacks; however, many of the models described can be applied to general helicopter operations. The

formulations are limited to the major events that occur during an attack helicopter deliberate attack and represent initial research to portray attack helicopter operations in JWAEP.

FACILITY LOCATION USING CROSS DECOMPOSITION
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Determining the best base stationing for military units can be modeled as a capacitated facility location problem with sole sourcing and multiple resource categories. Computational experience suggests that cross decomposition, a unification of Benders Decomposition and Lagrangean relaxation, is superior to other contemporary methods for solving capacitated facility location problems. Recent research extends cross decomposition to pure integer programming problems with application to capacitated facility location problems with sole sourcing; however, this research offers no computational experience. This thesis implements two cross decomposition algorithms for the capacitated facility location problem with sole sourcing and compares these decomposition algorithms with direct solution using branch and bound. For some problems tested, cross decomposition obtains better solutions in less time; however, cross decomposition does not always perform better than branch and bound due to the time required to obtain the cross decomposition bound that is theoretically superior to other decomposition bounds.

AAW EFFECTIVENESS OF THE DD-963 SPRUANCE CLASS DESTROYER: AN ANALYTIC MODEL
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Master of Science in Operations Research-September 1996
Advisor: W. Max Woods, Department of Operations Research
Second Reader: Robert E. Ball, Department of Aeronautics and Astronautics

A typical naval ship has multiple systems which can be used to defend itself against a cruise missile threat. These systems may consist of surface-to-air missiles, MK 45 guns and the Close-in-Weapon-System to name a few. Until recently each of these system's effectiveness against a cruise missile was assessed independently of the other systems onboard the ship. The purpose of this thesis is to develop an overall system effectiveness model for the DD-963 Spruance class destroyer. The model considers the integration of the defensive systems onboard, the availability and reliability of these systems and contains parameters that can be used to incorporate the crew's ability to employ the various weapon systems against a cruise missile threat.

ANALYSIS OF RUSSIAN AND SPANISH SUBSKILL TESTING AT THE DEFENSE LANGUAGE INSTITUTE
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Master of Science in Operations Research-September 1996
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Second Reader: Robert R. Read, Department of Operations Research

The Defense Language Institute is responsible for training military and government service personnel requiring a foreign language skill. Ten Subskill tests have been developed to evaluate the graduating students' language abilities and to determine if they have met the sponsor's Final Learning Objectives. The Subskill tests in some languages have been in place long enough that they can now be studied. This thesis examines these Subskill tests for both Russian and Spanish to determine if the tests have been developed and implemented in a manner to efficiently and consistently

discriminate between students of different abilities. Three different issues are treated. The ANOVA is used to identify Subskill tests with significant rater effects and the magnitude of those effects when they are present. Item Response Theory is used to examine the Subskill tests at the question level in order to identify questions that poorly discriminate between students of different abilities. In addition, the ability range that students are tested over is examined. Finally, methods using principal components and multiple regression are used to determine which tests, if any, can be eliminated with an acceptable loss of information about the students.

COMPARISON OF BRADLEY M2A2 AND M2A3 USING JANUS

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Robert Read, Department of Operations Research
Second Reader: Glen Roussos, U.S. Army Training and Doctrine Analysis Command

The U.S. Army is currently developing a new variant of the Bradley Fighting Vehicle, the M2A3 also know as the BFVS-A3. The new vehicle will include a number of modifications to the current M2A2 vehicle as a result of combat experience during Operation Desert Storm. The modifications have resulted from a need to upgrade the Bradley Fighting Vehicle System (BFVS) to facilitate enhanced command and control, lethality, survivability, mobility, and sustainability to defeat current and future threat forces.

The purpose of this thesis is to compare the two variants of vehicle in the Pre-test Modeling phase of the Model-Test-Model concept. This thesis used the Janus high resolution combat model, to simulate the vehicles and weapon systems under two scenarios, a Head-to-Head scenario, and a Force-on-Force scenario. The Head-to-Head scenario is a simulation of the future Limited User Test 2 to be conducted by TEXCOM. The Force-on-Force scenario is a simulated battle between a Bradley platoon and a Soviet style tank heavy company.

Data was gathered from the Janus created postprocessor files of the two scenarios. The analysis compared four measures of effectiveness (MOEs), in the areas of detection, engagement, lethality, and survivability. The aim of the analysis was to detect differences between the vehicle variants using the two sample T-test and the Mann-Whitney-Wilcoxen test.

AN ALTERNATIVE TESTING METHODOLOGY FOR TOW MISSILE TRAINING SYSTEMS

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Master of Science in Operations Research-September 1996
Advisor: Dan C. Boger, Department of Systems Management
Second Reader: Paul S. Bloch, Department of Operations Research

This thesis explores alternatives to current testing methodology being applied to two TOW missile training systems. This thesis contends that current program practices do not adequately prove system accuracy or system training value. Research emphasis is placed upon identifying those factors involved in assessing system accuracy that are currently being overlooked. The objective is that future government testing will address system accuracy and training value in detail. Following a description of current techniques, an alternative to current accuracy assessment is presented using the precepts of direct fire gunnery based upon a series of statistical treatments that quantify system accuracy and contract specification compliance. Data collection enhancements, potential test design modifications, and a methodical data analysis plan is presented. An alternative testing scenario is developed based upon the recommended changes in test methodology. Finally, observations and recommendations are provided pertaining to program management of the two TOW missile training systems in an effort to optimize program structure. The underlying premise is that the application of operations research skills to validate system performance will improve the final product fielded to U.S. Marines and Soldiers.

MASTER OF SCIENCE IN OPERATIONS RESEARCH

A METHODOLOGY FOR EVALUATING MINE ACTUATION DATA

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Second Reader: William Kroshl, Department of Operations Research

This thesis develops a methodology for evaluating mine actuation data. Computer models are developed to analyze actuation data obtained from the Mine Warfare Command by fitting various types of actuation curves to the data. For each actuation curve type, maximum likelihood estimates are used to determine those parameters resulting in the greatest probability of obtaining the observed data.

A STOCHASTIC SIMULATION OF A UNITED STATES NAVAL CONFLICT WITH A LAND-BASED OPPONENT: THE IMPACT OF C^{4}ISR

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Second Reader: Patricia A. Jacobs, Department of Operations Research

This thesis develops a low-resolution stochastic simulation model to assess the impact of the intelligence, surveillance and reconnaissance components of C^{4}ISR, and strike capabilities on the mission success of a United States carrier battle group (CVBG). The simulation uses a stochastic approach to model a two-day conflict between a CVBG and a land-based enemy which incorporates the randomness and uncertainty inherent in warfare. The simulation is implemented as a C++ computer program to develop a tool to analytically exercise a prospective new system in order to predict its possible effect on combat operations. Experiments were run which simulated a two-day battle in which the United States CVBG sensor availability, sensor accuracy, and weapons availability were varied to study their affect on the outcome of the battle. Statistical analysis techniques are used to quantitatively measure the results of the battle as the sensor and weapon parameters change.

A STOCHASTIC ENHANCEMENT TO THE ANALYST'S WORKBENCH

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Master of Science in Operations Research-September 1996
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Second Reader: Michael P. Bailey, Department of Operations Research

The Analyst's WorkBench is a deterministic integrated framework developed and used by the Weapons Planning Group at NAWC China Lake. The model has no stochastic capability which requires all analysis to be conducted using parameters based on expected values of occurrence. This thesis develops a stochastic enhancement that can be incorporated in the Analyst's WorkBench. Independent identically distributed (IID) events can be generated by calls to the enhancement as a parametric input. To demonstrate the application of a stochastic process within the Analyst's WorkBench, a test scenario of a ship defense model is developed. A large scale missile attack is simulated deterministically and stochastically to demonstrate the differences of a random probability of successful defense vice an expected value of success. It is shown that the stochastic results provide a more realistic simulation and that the deterministic results overstate the capability of a system subject to random events that can be described by a statistical distribution.

A METHODOLOGY FOR DETERMINING STUDENT VALUE IN EXPLOITING AIRLINE RESERVATION TECHNOLOGIES TO IMPROVE NAVY TRAINING QUOTA MANAGEMENT

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Master of Science in Operations Research-September 1996
Advisor: Samuel H. Parry, Department of Operations Research
Second Reader: Harold J. Larson, Department of Operations Research

The Navy trains over 350,000 students a year. Quotas for the number of students to train are based on current and projected manning levels, as well as anticipated force requirements. Last year, students awaiting instruction exceeded 1.3 million mandays while, simultaneously, over 25% of the Navy's 330,000 technical training seats went unfilled. The number of unfilled seats in classrooms, coupled with the large number of students awaiting instruction, identified the need to more closely manage the allocation of quotas. The use of yield management has been explored to determine if airline reservation technologies are applicable to solving the Navy training quota management problem. In order to apply yield management to the Navy training problem, the concept of value must be determined as it relates to a student attending a Navy training class. While airlines measure value in revenue generated, the Navy has no way of placing value on a particular student attending a particular class. This thesis identifies a methodology for determining student value within the Navy Training Quota Management System.

TOWARD ASSESSMENT OF DOMINANT BATTLESPACE AWARENESS: A REMOTE SENSOR SYSTEM MODEL

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Two broad concepts have begun to permeate U.S. military strategic planning since the end of the Gulf War: the revolution in military affairs (RMA) and dominant battlespace awareness (DBA). An RMA represents a basic change in the conduct of warfare which incorporates new technologies, operational innovation and organizational changes. DBA refers to the military's ability to efficiently obtain and effectively use information to dominate an opposing force. This thesis is a study of a stylized warfare scenario involving elements of DBA and RMA. Specifically, U.S. attack aircraft attempt to prevent enemy transporter-erector-launchers (TELs) from harassing neighboring countries with theater ballistic missiles. The U.S. aircraft may be aided by use of unattended ground sensors (UGSs); the enemy TEL activities are correspondingly enhanced by decoy TELs. The model described allows the combat advantage of each side to be quantitatively compared. Trend analysis demonstrates the benefits of deception and the potential of UGSs.

EVALUATING CARRIER BATTLEGROUP ANTI-AIR WARFARE CAPABILITY IN A COMPUTER-AIDED EXERCISE

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Second Reader: George Conner, Department of Operations Research

One of the primary training tools available to a Unified Commander in Chief (CINC) for training his staff on their joint mission essential tasks (JMETLs) is a command post exercise supported by a computer simulation model, commonly referred to as a Computer Aided Exercise (CAX). Currently, little quantitative data are captured during the exercise allowing for quick postexercise analysis of critical staff processes inherent in the CINC's exercise training objectives. The objective of this thesis is to develop an exercise analysis methodology for evaluating the execution of joint tasks during the conduct of a CAX. Specific objectives are first to demonstrate a methodology for developing quantifiable

measures of effectiveness (MOEs). These MOEs must reflect the hierarchical structure of tasks given in the Universal Joint Tasks List (UJTL) as applied to three levels of war (vertical linkage), and functionality considerations between related enabling tasks (horizontal linkage). The second specific objective is to determine methods to capture task performance data within the design of the simulation. This is intended to support the exercise analysis by capturing critical decisions, assumptions, and causal factors which, in turn, lead to observed scenario outcomes. This objective involves demonstrating the methodology in an exercise conducted utilizing the Joint Theater Level Simulation (JTLS). The effort in this thesis is focused exclusively on joint tasks involving force protection, particularly air defense, of a battlegroup in the littoral region; however, the principles of the methodology are applicable to the entire spectrum of tasks in the UJTL.

APPLICATIONS OF LOGISTIC REGRESSION TO IDENTIFY FACTORS THAT AFFECT THE MEASURES OF THE ARMY PERSONNEL READINESS
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Second Reader: James R. Thomas, PERSCOM

The purpose of this thesis was to use regression models to investigate factors that might be used to predict the monthly aggregated measures of Army personnel readiness. To that end, logistic regression analysis was conducted using Army personnel data that ranged from October 1991 thru September 1995. There were two measures (or response variables) for this study; the proportion of Army units with personnel ratings at least as high as their Authorized Level of Organization, and the proportion of Army units that achieved a personnel rating of 3 or better. In an attempt to identify potential factors that may influence these measures, ten covariates were selected for the analysis. This analysis focused primarily on the development of six logistic regression models that were used to forecast the two readiness measures one month, two months, and three months into the future. The results of this study may benefit Army personnel managers by providing them with an increased understanding of the factors that significantly affect the two quantifications of Army personnel readiness.

UNITED STATES MARINE CORPS MILITARY OCCUPATIONAL SPECIALTY (MOS) ASSIGNMENT MODELING USING AUGMENTATION PROBABILITIES
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Advisor: William G. Kemple, Department of Operations Research

An assignment model is developed which considers augmentation probabilities when assigning Marine officers Military Occupational Specialties (MOSs) at The Basic School (TBS). The goal is to increase the expected number of augmentees in those MOSs that are chronically short in company and field grade officers. Results are compared to the current process of assigning MOSs based on a “quality spread” achieved by dividing the TBS class and MOSs available into thirds and to a similar policy of division into halves.

Regardless of the model used, the expected number of augmentees does not vary appreciably from the historical averages. Not adhering to the quality spread policy in the past has not impacted augmentation probabilities greatly. Dividing the class into halves vice thirds provides approximately the same expected number of augmentees as the current policy and would give more officers from the top of the class one of the their top choices. The only other change to assignment policy which may be warranted is restricting assignment for several MOSs (MOS 4002-data processing, 7208-air defense, and 7210-air support) to assignment from the top third or half of the class.

DETERMINING AN OPTIMAL BULK-CARGO SCHEDULE TO SATISFY GLOBAL U.S. MILITARY FUEL REQUIREMENTS

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Second Reader: Bob Vassian, Department of Operations Research

The Defense Fuel Supply Center (DFSC) is responsible for the acquisition, storage, and distribution of bulk petroleum products to support worldwide military service requirements. DFSC delivers these fuel products around the globe through a fleet of bulk-cargo tankers which are controlled by Military Sealift Command (MSC). The current method of scheduling cargo deliveries is done manually and takes approximately three to five days to complete, requiring close interaction with MSC. The cargo scheduling planners must specify a feasible load port and time, and discharge port and time for each cargo such that military fuel demands are met and the tankers are utilized efficiently. Currently, there are no mathematical models available to assist scheduling planners in assigning an efficient cargo schedule

The objective of this thesis is to aid scheduling planners in determining the most efficient cargo sequencing plan. This is achieved through the development of a mathematical model which represents the cargo scheduling problem, and the design of a microcomputer interface that allows use of the model as a management tool which seeks to maximize the number of cargo deliveries. Specifically, an optimization model utilizing the network structure of the maximum flow model, which is accessed through a spreadsheet-based interface, is used to solve the cargo scheduling problem.

A REACTIVE TARGET ACTIVE ASW SONAR SEARCH TACTICAL DECISION AID

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Second Reader: James Sanders, Department of Physics

This thesis develops, implements and tests a Tactical Decision Aid for a Reactive Target ASW Active Search. The model uses a Bayesian Filtering Process to fuse information from a real world search conducted by several assets with information from a Monte Carlo Simulation that encompasses five hundred equally-likely different possible initial positions and behaviors of the real target. A Reactive Target Model resembles the behavior of a target that is always aware and reacts because of the presence and activity of the searchers. An initial "prior," or best estimate of the location of the target, is updated using the movement of the simulated targets, the negative information conveyed in an unsuccessful search over a period of time and the positive information implied in a contact report. The search effort is measured using a Fixed Scan Stochastic Model that solves the Sonar Equation limited by noise and reverberation. As a result of updating the prior, a "posterior" distribution is obtained. The Law of Total Probabilities is used to render a probability map of the location of the Target by mapping color intensities to probabilities. A recursive expression for evaluating a contact report is also developed.

MASTER OF SCIENCE IN OPERATIONS RESEARCH

ANALYSIS OF THE AIRCRAFT CARRIER ELECTRIC MOTOR REPAIR SHOP USING SIMULATION AND ANIMATION

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Master of Science in Operations Research-September 1996
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Second Reader: Arnold H. Buss, Department of Operations Research

While operating within the Battle Force Intermediate Maintenance (BFIMA) Activity, emergent maintenance requests issued by ships in company with the carrier for motor rewind and overhaul work naturally occur whenever other suitable and better equipped maintenance assets such as tenders or nearby shore facilities are not available. To evaluate the capability of the carrier's electric motor repair shop to support the BFIMA, a simulation and animation model of the repair process was developed. The model computed the mean number of rewinds and overhauls and their average repair turnaround times as shop resource levels and arrival rates varied during one 6 month deployment. The analysis shows that addition of another bake oven improves readiness by significantly reducing mean repair times.

OPTIMIZATION METHODS FOR MIXED MINEFIELD CLEARANCE

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This thesis describes the development and implementation of an improved optimization feature for the minefield clearance TDA MIXER. A constrained form of MIXER's original local optimal search method is proposed, followed by an exhaustive search method, and then a simulated annealing method.

Computational efficiency and program run times are examined for the exhaustive search method. Also, a performance comparison of "optimal" solutions for the local search and simulated annealing methods is given. A final version of the optimization feature incorporates all three search methods.

AN ASSESSMENT OF THE IMPACT OF FUSED MONOCHROME AND FUSED COLOR NIGHT VISION DISPLAYS ON REACTION TIME AND ACCURACY IN TARGET DETECTION

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Second Reader: Thomas Halwachs, Department of Operations Research

Night Vision Devices (NVDs) employed by the military fall into two categories: Image Intensifiers (I^2) also known as Night Vision Goggle (NVGs) and Infrared (IR). Each sensor provides unique visual information not available to the unaided human visual system. However, these devices have limitations and they have been listed as a causal factor in many crashes of military aircraft at night. Researchers hypothesize that digitally fusing the output from these sensors into one image and then artificially coloring the image will improve an NVD user's visual performance. The purpose of this thesis was to determine if fusion and coloring of static, natural scene NVG and IR imagery will improve reaction time and accuracy in target detection.

Pairs of static images from three different scenes were obtained simultaneously from NVG and IR sensors. The six original images were fused pixel by pixel and then colored using a computer algorithm. A natural target was moved to two other coherent positions in the scene or completely removed, resulting in twenty-four images for each of the three natural scenes. Six subjects viewed the images randomly on a high-resolution monitor, rapidly indicating on a keypad if the target was present (1) or absent (2). Reaction time and accuracy were recorded. An ANOVA on the output and a subsequent review of the images revealed that fusion significantly impacted local (target) contrast and that, coupled with scene content, decreased performance on the task. Fusion and coloring results were not superior here, which differed from results on other types of tasks, however, more research is needed to completely assess this technology.

RELATING THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY TO MARINE JOB PERFORMANCE
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Master of Science in Operations Research-September 1996
Advisor: Robert R. Read, Department of Operations Research
Second Reader: Harold J. Larson, Department of Operations Research

This thesis develops a method to reconfirm the relationship between an individual's Armed Services Vocational Aptitude Battery (ASVAB) scores and his performance at his initial course of instruction in the Marine Corps. Validity coefficients are developed to ensure that the ASVAB correctly predicts success at these initial training courses. Once the ASVAB is shown to correctly predict success at Marine Corps courses, the thesis concentrates on two statistical methods to explore the classification of youths into marine jobs. The first method, discriminant analysis, is used as a check of the current classification process. Next, a tree-based regression method is used to evaluate if further employment of ASVAB scores can more appropriately place trainees into Marine Corps jobs. These methods ultimately afford the Marine Corps an opportunity to use existing information to enhance the successful classification of young Marines into appropriate courses, thereby increasing their chances of successfully completing their initial training.

OPTIMAL AIRCRAFT CARRIER DEPLOYMENT SCHEDULING
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Master of Science in Operations Research-March 1996
Advisor: Siriphong Lawphongpanich, Department of Operations Research

The Navy's peacetime mission is "to conduct forward presence operations to help shape the strategic environment by deterring conflict, building interoperability, and by responding, as necessary, to fast breaking crises with the demonstration and application of credible combat power." To meet this mission, the Navy deploys aircraft carriers to forward positions throughout the world. A new nuclear powered aircraft carrier costs over $3.4 billion dollars and when deployed carries over 6,000 personnel onboard. Considering the cost and the man hours involved in carrier operations, judicious and effective use of these valuable assets is imperative.

The CINCPACFLT Operations Department maintains a five year deployment plan for the six carriers assigned to the Pacific Fleet. Currently, the deployment schedule is produced manually. A feasible five year plan typically takes the carrier scheduling officer one week to generate. This thesis presents an optimization based tool to assist in constructing deployment schedules that maximize the forward presence of Pacific Fleet carriers. The underlying optimization model is different from those in the literature. Instead of using a set covering approach, the problem is formulated as a shortest path problem with side constraints. This formulation allows the problem to be solved more rapidly, thus allowing more opportunities for sensitivity and trade-off analyses.

STRATEGIC SEALIFT PROTECTION IN A MAJOR REGIONAL CONFLICT

Gordon Alexander Silloway-Lieutenant, United States Navy
B.A., University of Southern California, 1989
Master of Science in Operations Research-September 1996
Advisor: Wayne Hughes, Department of Operations Research
Second Reader: Al Bottoms, Undersea Warfare Academic Group

This thesis examines the North Korean threat to U.S. strategic sealift in a single major regional conflict (MRC) on the Korean peninsula. The focus of this campaign level analysis is the ability of U.S. and Korean maritime patrol aircraft (MPA) to intercept North Korean Romeo-class attack submarines as they operate in South Korean waters. An MPA search model is developed which details current tactics and operating parameters for the P-3C Orion patrol aircraft. Results obtained from this model are expressed as the probability that a North Korean submarine in a special geographic sector will be detected and destroyed on any given day of the campaign. Two alternative means of conducting anti-submarine operations in the Korean MRC are also presented. Campaign and tactical level recommendations are made based on the information provided by the analysis.

DEVELOPMENT OF A FORCED ENTRY MISSION OBJECTIVE SELECTION ALGORITHM FOR IMPLEMENTATION INTO THE JOINT WARFARE ANALYSIS EXPERIMENTAL PROTOTYPE

William Nicholas Allen Slavik-Captain, United States Marine Corps
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Master of Science in Operations Research-December 1995
Advisor: Samuel H. Parry, Department of Operations Research

This thesis develops an algorithm for the selection of objectives for forced entry military operations in a theater level campaign model. The Joint Warfare Analysis Experimental Prototype (JWAEP) is an interactive, 2-sided, theater-level combat model based on an arc-node representation of ground, air, and littoral combat. It may be used in an interactive gaming mode or a closed-form stochastic analysis mode. The need for active mission assignment in the analysis mode mandates that objectives for combat operations be nominated during each planning cycle to adapt to the changing face of the battlefield. JWAEP would execute an initial feasibility check for enemy occupied or controlled nodes against the assets available to the friendly forces. Based on the probabilistic representation of the enemy units occupying a node, the algorithm determines the relative value of perceived maneuver units and static targets. This is then compared to the relative perceived strength of the units in that node and surrounding nodes which may also defend against the operation. The perceived strength determines the threat; it is calculated for each force capable of executing the attack. The most desirable node for each force, given value and threat, is sent to the appropriate planning module. The principal focus of this thesis is on the determination of the target value parameter and the node defensibility parameter as they are used to nominate and rank possible objectives.

PROBABILITY MODELS FOR ASSESSING THE VALUE OF BATTLE DAMAGE ASSESSMENT IN THE DEFENSE AGAINST SEQUENTIAL THEATER MISSILE ATTACKS

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Master of Science in Operations Research-March 1996
Advisor: Donald P. Gaver, Department of Operations Research

This thesis seeks to use probability models to investigate the effects and value of battle damage assessment (BDA) information availability on sequential tasks encountered in the defense against missile attacks. Different levels of information will have different impacts on the outcome of the battle. Additional information could increase the effectiveness of the defensive weapon system. On the other hand, the enemy could use deception techniques, electronic warfare (EW) and Decoy measures on the information gathering methods to disrupt the acquisition of information which would decrease the effectiveness of defensive weapons. In the models, we show how to best allocate limited

resource; i.e., the available kill time, to maximize the reward. We define a measure of effectiveness (MOE) for information which can be used for evaluating information value and decision making. We discuss different strategic alternatives and information value for both defenders and attackers in electronic warfare (EW).

PERFORMANCE MEASURE ANALYSIS OF COMMAND AND CONTROL ORGANIZATIONAL AND TASK STRUCTURES
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Master of Science in Operations Research-September 1996
Advisor: William G. Kemple, Department of Operations Research
Second Reader: Michael G. Sovereign, Department of Operations Research

Recent joint operations such as the ones in the Persian Gulf, Somalia, Haiti, and Bosnia are examples of some of the missions the military is expected to conduct in the future. The missions and available forces varied, and not surprisingly, so did the command and control architectures.

The purpose of the initial A2C2 experiment was to examine the relationships between organizational structures and task structures involving competition for scarce assets, to serve as an integration vehicle for the project's previous efforts, and as a baseline for further research. This thesis attempts to answer the following questions: 1) Are there statistically significant differences in the outcomes of competition events based on the particular experimental conditions imposed? and 2) Is there a viable method for determining the processes involved in the resolution of competition events, and can it be accomplished without the use of human monitors, i.e., can a tool be developed to determine the processes used in the resolution of competition events after an experiment is conducted?

The answer to both questions is yes; although in the case of the first question, a qualified yes. Programs the author developed to satisfy the second question are included.

SENSORS IN OBJECT ORIENTED DISCRETE EVENT SIMULATION
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Master of Science in Operations Research-September 1996
Advisor: Arnold H. Buss, Department of Operations Research
Second Reader: James Eagle, Department of Operations Research

The growing cost of physical tests and evaluations of military systems has resulted in increased use of computer simulations to provide decision support information. Many such systems, such as weapons and countermeasure systems, rely on sensors. Hence, development of widely applicable computer models for sensors is vitally important. This research investigates the possibility of developing sensor simulations as components for use in models with varying fidelity and purpose. Development of abstractions is emphasized to maximize the applicability of components in a variety of modeling contexts. Concrete examples of reusable sensor components are demonstrated in working models and a preliminary design for a generalized modeling framework is proposed.

DETERMINING AN OPTIMAL BULK-CARGO SCHEDULE TO SATISFY GLOBAL U.S. MILITARY FUEL REQUIREMENTS

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Second Reader: Bob Vassian, Department of Operations Research

The Defense Fuel Supply Center (DFSC) is responsible for the acquisition, storage, and distribution of bulk petroleum products to support worldwide military service requirements. DFSC delivers these fuel products around the globe through a fleet of bulk-cargo tankers which are controlled by Military Sealift Command (MSC). The current method of scheduling cargo deliveries is done manually and takes approximately three to five days to complete, requiring close interaction with MSC. The cargo scheduling planners must specify a feasible load port and time, and discharge port and time for each cargo such that military fuel demands are met and the tankers are utilized efficiently. Currently, there are no mathematical models available to assist scheduling planners in assigning an efficient cargo schedule

The objective of this thesis is to aid scheduling planners in determining the most efficient cargo sequencing plan. This is achieved through the development of a mathematical model which represents the cargo scheduling problem, and the design of a microcomputer interface that allows use of the model as a management tool which seeks to maximize the number of cargo deliveries. Specifically, an optimization model utilizing the network structure of the maximum flow model, which is accessed through a spreadsheet-based interface, is used to solve the cargo scheduling problem.

ANALYSIS OF DEFENSE LANGUAGE INSTITUTE'S AUTOMATED STUDENT QUESTIONNAIRE DATA

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Second Reader: Lyn R. Whitaker, Department of Operations Research

This thesis explores the dimensionality of the Defense Language Institute's (DLI) primary student feed back tool - the Automated Student Questionnaire (ASQ). In addition, a data set from ASQ 2.0 (the newest version) is analyzed for trends in student satisfaction across the sub-scales of sex, pay grade, and Defense Language Proficiency Test (DLPT) results.

The method of principal components is used to derive initial factors. Although an interpretation of those factors seems plausible, they are subjected to a factor analysis rotation (varimax) and five factors are determined and interpreted in terms of student satisfaction with DLI's: (1) academic environment, (2) military environment, (3) non-barracks dormitory living conditions, (4) official and supplemental course audio tapes, and (5) service unit's computer learning centers. From the factor loading matrix factor scores equations are developed for use in a sub-scale trend analysis.

Using non-parametric procedures, each factor is checked for differences in central tendency by sex, pay grade, and DLPT score (DLPT consists of three tests DLPTL, DLPTR, DLPTS). From this analysis the following results derive: (1) sex has no effect on any of the factors, (2) pay grade affects satisfaction with the military environment, and (3) DLPTL, DLPTR, and DLPTS affect satisfaction with the academic environment, and DLPTS also affects satisfaction with the computer learning centers.

MASTER OF SCIENCE IN OPERATIONS RESEARCH

A METHODOLOGY FOR EVALUATING A JOINT MOBILIZATION PLAN USING THE JOINT THEATER LEVEL SIMULATION (JTLS)

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One of the primary training tools available to a Joint Commander in Chief (CINC) for training his staff on their joint mission essential tasks is a command post exercise supported by a computer simulation model. Computer-Aided Exercises (CAXs) are an essential part of training a component staff, however one weakness lies in the measurement of the level of training received by the players. In most CAXs the players rapidly disperse after the exercise, and not only is no quantitative data captured but in most cases they don't receive a detailed debrief. This research presents a methodology for evaluating the performance of joint mobilization tasks as set forth in the Universal Joint Task List (UJTL). The UJTL provides both the staff and evaluators with a common document outlining the critical events and activities which require successful accomplishment. The UJTL is organized in such a manner which defines activities such as logistics, intelligence, and force protection.

It is the purpose of this thesis to provide a methodology for objectively assessing the effectiveness of a staff's joint mobilization plan. Experimental runs using the Joint Theater Level Simulation (JTLS) are presented to demonstrate the methodology and the subsequent analysis process.

DETECTABILITY OF THE MEDIUM ALTITUDE ENDURANCE UNMANNED AERIAL VEHICLE (MAE UAV) "PREDATOR"

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This thesis assessed the detectability of the Medium Altitude Endurance Unmanned Aerial Vehicle (MAE UAV) "Predator," in support of Advanced Concept Technology Demonstration (ACTD) objectives for the Defense Evaluation Support Activity. The scope of this thesis is limited to the Predator air vehicle utilized in a high-intensity scenario against a "Soviet" low-altitude air defense threat.

The thesis presents a detailed analysis of both threat characteristics and air vehicle signature data required to support the detectability analysis. The analysis utilizes Digital Integrated Modeling Environment air defense models and all source reporting to draw and present conclusions on the detectability of the air vehicle and the effect of detection on mission accomplishment.

This thesis is intended to provide direct input into the ACTD, providing the future users with detection data needed to develop doctrinal risk assessment tools against which to make deployment decisions for the MAE UAV. The results of this study may serve as a reference in the long term development of MAE UAV tactics, techniques, and procedures by future users. Results may additionally be used to enhance future vulnerability assessments.

A METHODOLOGY FOR EVALUATING FORCE PROTECTION DURING A COMPUTER-AIDED EXERCISE

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The development of a proficient staff at the Joint Level is primarily accomplished through the use of computer-aided exercises (CAXs). The primary purpose of these exercises is to increase the readiness of the staff to perform actual missions from standing up a Joint Task Force (JTF) to redeployment of the forces. A measure of the tasks required of a staff is accomplished through a Mission Essential Task List from the Universal Joint Task List (UJTL). This document defines critical events and activities that must be accomplished to achieve the desired mission goals. The measurement of that performance from actual data from the computer model has been limited. This thesis provides a methodology that assists in the evaluation of force protection. This quantitative analysis can be provided quickly and concurrent to the exercise. Immediate feedback helps the staff and commander to understand why an outcome happened through linkage of UJTL tasks. This methodology was tested using the Joint Theater Level Simulation and the results demonstrating the methodology and analysis of the output are presented.

POSITIONING AND TRANSPORTING AMMUNITION IN SUPPORT OF THE DUAL MAJOR REGIONAL CONTINGENCY SCENARIO

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This study is concerned with the problem of optimizing the transportation of select ammunition types in support of the dual Major Regional Contingency (MRC) scenario. The purpose is to provide decision makers with alternative courses of action when transporting ammunition in this scenario and the problems that may be encountered. The tool used to accomplish this goal is an optimization model developed and implemented using the General Algebraic Modeling System (GAMS). The model optimally routes and schedules the ammunition distribution ships serving in this scenario. The ships used are a mix of Navy controlled ammunition ships (AK) and ships of the Ready Reserve Force (RRF). To examine the problems associated with the distribution of ammunition in this scenario, four cases were developed. Analysis of these cases with the optimization model investigated three main problems associated with the distribution of ammunition in the Western Pacific (WESTPAC) in support of the dual MRC scenario. These problem areas are: insufficient supply of ammunition at the supply ports, inadequate numbers of ships available to move ammunition, and a decrease in the ability of a supply port to handle ammunition. All of these problems will affect the Navy's ability to conduct its missions in support of the dual MRC scenario.

ROUTE, AIRCRAFT PRIORITIZATION AND SELECTION FOR AIRLIFT MOBILITY OPTIMIZATION

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The *Throughput II* mobility optimization model (Morton, Rosenthal, and Lim, 1995) was developed at the Naval Postgraduate School for the Air Force Studies and Analysis Agency (AFSAA). The purpose of *Throughput II* is to help answer questions about the ability of the USAF to conduct airlift of soldiers and equipment in support of major military

operations. Repeated runs of this model have helped AFSAA generate insights and recommendations concerning the selection of aircraft assets. Although *Throughput II* has earned the confidence of AFSAA, repeated applications are hampered by the fact that it can take over three hours to run on a fast workstation. This is due to the model's size; it is a linear program whose dimensions can exceed 100,000 variables, 100,000 constraints, and 1 million nonzero coefficients, even after extensive model reduction techniques are used. The purpose of this thesis is to develop heuristics that can be performed prior to running *Throughput II* in order to reduce the model's size. Specifically, this thesis addresses the fact that the *Throughput II* formulation has many variables and constraints that depend on the number of available routes for each aircraft. The goal is to carefully eliminate routes so as to make the problem smaller without sacrificing much solution quality.

AIRFIELD AGGREGATION AND ROUTE SELECTION METHODS FOR STRATEGIC AIRLIFT

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Due the remarkable growth in the size and complexity of airlift operations, there is an increased need for planning tools to assist decision makers with issues ranging from selecting the number and types of aircraft for an airlift fleet to making informed decisions with respect to investing or divesting in overseas air bases. In Fiscal Year (FY) 94 research was initiated in the Operations Research Department of the Naval Postgraduate School in response to a request from the United States Air Force Studies and Analyses Agency and resulted in the development of a high fidelity strategic airlift optimization model called *Throughput II*. The model is formulated as a multi-period, multi-commodity linear programming model for determining the maximum on-time throughput of cargo and passengers that can be transported with a given fleet or given network, subject to appropriate physical and policy constraints. Troop and equipment movement requirements are specified by the Time Phase Force Deployment Data (TPFDD). An optimization model that utilizes the full level of detail available in a TPFDD would be of intractable size. Moreover, it is not necessary to build a model with such a fine level of detail in order to obtain the important insights required to assist decision makers. Therefore *Throughput II* replaces the potentially large set of airfields with a smaller set of centroids and schedules aircraft through these aggregated airfields. Currently route selection is performed manually, by an expert, who incorporates a variety of factors based on his/her experience. In this thesis we develop techniques for selecting a set of candidate routes for any deployment scenario without requiring historical data or extensive interaction with an expert. An analyst should be concerned about two potentially detrimental effects of these preprocessing procedures. First, unfeasibility may be introduced by aggregation and second, *Throughput II* may provide suboptimal solutions since we consider a limited number of routes. To address these issues, a postprocessing step can be used to screen for constraint violations and to perform sensitivity analysis with respect to alternative routing options.

LONG RANGE INTER DEPLOYMENT TRAINING CYCLE SCHEDULE FOR THE P-3 COMMUNITY

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The P-3 community consists of 12 Active (effective 01 Oct 96) Maritime Patrol Aviation (MPA) squadrons which deploy to various parts of the world conducting numerous missions. Before deployment, each squadron undergoes a work-up period called the Inter-Deployment Training Cycle (IDTC). The purpose of the IDTC is to adequately prepare a squadron for deployment by conducting training, inspections, and evaluations. A plan is developed to schedule squadron and wing assets effectively to ensure quality training that will improve operational effectiveness on deployment.

The difficulty is developing and IDTC schedule for an individual squadron that has minimal impact on the other eleven squadrons. A schedule that efficiently coordinates a squadron's IDTC improves the effectiveness of a squadron. Moreover, a master schedule that considers the community as a whole will improve the overall effectiveness of the community.

This thesis develops a master schedule for the P-3 community that efficiently schedules an IDTC at the squadron level staying within the desires of the squadron commanders. Additionally, an IDTC shell is incorporated into the employment plans throughout the community avoiding conflicts at all levels. Significant savings are gained by optimally scheduling the NATOPS evaluations.

A COMPARISON OF AIRCRAFT DEPOT INDUCTION PROCESSES: ASPA AND PDM
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The purpose of this thesis is to compare two predominant decision processes for aircraft depot inductions. The first process, Aircraft Service Period Adjustment (ASPA), is currently applied to the majority of Naval aircraft. The decision to induct an aircraft through ASPA is based on the results of subjective, periodic inspection. The second process, Programmed Depot Maintenance (PDM), is used by the U.S. Air Force. The Navy is also experimenting with its own form of PDM, called Phased Depot Maintenance. The PDM concept is based on the idea that regular overhaul of aircraft reduces man-hour requirements, turn-around time, and the variability of planning factors. The decision to induct an aircraft under PDM is entirely objective, as it is based solely on calendar time. A statistical comparison of the long term effects of ASPA and PDM is achieved by analyzing the output data of a simulation model designed in this thesis. Model output includes maintenance man-hour and turn-around time per depot overhaul, and the cumulative time in the depot and number of depot periods over the length of the simulation. The analysis provides insight into the benefits and trade-offs involved with each decision process.

VALIDATING AND IMPROVING EXISTING JLOTS THROUGHPUT MODELS WITH THE USE OF HISTORICAL WEATHER DATA
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The practice of Joint Logistics Over the Shore (JLOTS), whereby strategic sealift assets are off-loaded without the benefit of fixed port facilities has emerged as one viable technique which could alleviate certain situational sustainment problems. The ability to successfully conduct JLOTS operations, however, is presently limited by several factors, the most significant of which is the dependency of JLOTS operations upon favorable wind, weather, and sea state conditions. Presently, the few analytical JLOTS throughput models in existence have very limited incorporation of environmental parameters.

With this in mind, this thesis attempts to both validate and improve the most widely acclaimed JLOTS throughput model, the Joint Over the shore Transportation Estimator (JOTE) developed by the Logistics Management Institute (LMI). The validation centers upon identifying the demands placed upon the user when employing JOTE as well as assessing the validity of its computational methodology. As a means of improving JOTE and rendering it more viable as a planning tool, this thesis introduces a supplement entitled the SEA-STATE-CALC package which facilitates both site and time specificity in the most crucial input parameters to the JOTE model. By helping to identify time periods in

which sea state conditions threaten JLOTS operations, the SEA-STATE-CALC package services the planning needs of its true client, the JLOTS commander.