

# **MASTER OF SCIENCE IN OPERATIONS RESEARCH**

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## **ANALYSIS OF THE DETERIORATION RATE OF SHIP HANDLING PROFICIENCY OF SURFACE WARFARE OFFICERS ON SHORE DUTY**

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**B.S., United States Naval Academy, 1994**

**Master of Science in Operations Research-June 2000**

**Advisor: William K. Krebs, Department of Operations Research**

**Second Reader: Thomas W. Lucas, Department of Operations Research**

This thesis examines the deterioration of ship handling proficiency of Surface Warfare Officers on shore duty. A Surface Warfare Officer (SWO) develops ship handling proficiency during his or her first and second ship tours, then spends two or more years ashore. Upon returning to sea duty, an officer is expected to be proficient in ship handling even though it has been two years since the last shipboard evolution. Ashore SWOs were tested to determine whether their ship handling skills or knowledge about navigation rules had degraded over time. During the first phase of the experiment, subjects were immersed in a virtual environment to assess procedural knowledge of a ship handling task. The second phase of the experiment, designed to measure declarative knowledge of ship handling handling, consisted of a short written test. The results of the experiment showed no deterioration of SWOs ship handling skills over time. The results did show a significant deterioration of declarative knowledge of navigation rules. Actual or potential applications of this research include revising current Surface Warfare Officer training programs to account for the fact that not all knowledge is lost to memory equally. Periodic refresher training for SWOs on shore duty is also suggested by these results.

**DoD KEY TECHNOLOGY AREAS:** Manpower, Personnel, and Training, Human Systems Interface, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Manpower, Personnel, and Training

## **A COST MODEL FOR ESTIMATING OPERATING AND SUPPORT COSTS FOR UNITED STATES NAVY (NUCLEAR) SUBMARINES**

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**Master of Science in Operations Research-June 2000**

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This thesis attempts to formulate a parametric cost model to estimate the annual operating and support (O&S) cost of future U.S. Navy (nuclear) submarines, based on presumed physical characteristics and manpower expectations. Source data for the analysis is obtained from the Navy's VAMOS database. Using regression analysis techniques, cost estimating relationships are developed for three assumed cost drivers – manpower, length, and submerged displacement. However, the analysis reveals that there is no significant relationship between annual O&S cost and the three assumed cost drivers. Therefore, an alternative method of estimating annual O&S cost is presented using probabilistic assessment of cost based on the empirical annual O&S cost distribution. The probabilistic assessment method allows decision-makers and cost analysts to estimate the annual O&S cost for which there is a desired probability that the true annual O&S cost of a new submarine will not be exceeded. For example, historically, 80 percent of all SSNs have experienced annual O&S costs

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of less than \$27 M (CY99\$), while the remaining 20 percent have experienced annual O&S costs greater than \$27 M (CY99\$). So, loosely speaking, one can be approximately 80 percent confident that the annual O&S cost of a newly acquired SSN will be no more than \$27 M (CY99\$). Similar results can be obtained for any SSN or SSBN, and for any desired probability.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles - Ships and Watercraft, Other (Cost Estimation)

**KEYWORDS:** Government, Cost Estimating, Submarines, Operating and Support, Statistics/Regression

### AN INTELLIGENT AGENT SIMULATION OF SHIPBOARD DAMAGE CONTROL

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A fire on board a ship presents special challenges. It requires not only special anti-fire devices but well-trained teams of firefighters. Since crews rotate periodically, there is a need for ongoing personnel training and not all crew members have the same amount of training. A significant problem is how to assess the effectiveness of a team of firefighters with different skills in a real situation. A team should work together efficiently and follow standard procedures correctly if it is to successfully extinguish the fire within a reasonable period of time and with minimum damage. The question is: What skills are of most importance to a successful team of firefighters? It is difficult to carry out physical experiments without risking human lives and material losses. This thesis uses a reactive agent-based simulation to study the importance of different firefighting skills and anti-fire devices to the prosecution of fire on board a ship.

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

**KEYWORDS:** Artificial Intelligence, Fire, Firefighters, Firefighting Skills, Anti-Fire Devices, Stochastic Modeling

### THE RELATIONSHIP BETWEEN A SUBMARINE'S MAXIMUM SPEED AND ITS EVASIVE CAPABILITY

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**Second Reader: James N. Eagle, Department of Operations Research**

The experiences of submarine warfare from WWI and WWII have generally dictated maximum speed when designing conventional submarines. Technological development of submarine and anti-submarine weapons, however, requires examination of submarine warfare and tactics. This thesis focuses on a coastal conventional submarine's ability to survive, as a function of its maximum speed, when attacked by a light anti-submarine warfare (ASW) torpedo. It also evaluates the maximum speed with which the submarine should be equipped to ensure a specified probability of survival. The measure of effectiveness (MOE) is the probability that the submarine, operating up to maximum speed and launching only one set of countermeasures, is not caught by the torpedo.

The investigation builds on a discrete event simulation model. The systems simulated are a submarine, a light ASW torpedo, and a countermeasure system consisting of one decoy and four jammers. The results show that maximum speed of a submarine does effect the submarine's evasive performance between 12 and 18 knots. The simulated model reached a maximum probability of survival at 18 knots. That result should be regarded as a minimum since a real life system might require a higher maximum speed to reach its greatest probability of survival.

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

**KEYWORDS:** Conventional Submarines, Anti-Submarine Warfare Torpedoes, Torpedo Countermeasure Systems

### **A FAST HEURISTIC FOR TOMAHAWK LAND-ATTACK PREDESIGNATION**

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**Master of Science in Operations Research-June 2000**

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The Tomahawk Land-Attack Missile (TLAM) is a lethal, accurate, and long-range weapon that has provided the National Command Authority with the ability to respond with force to crises without committing troops or necessitating a large military build-up. When either the National Command Authority or regional Commander in Chief authorizes the use of TLAMs against specified targets, predesignation determines which ship or submarine will fire its missiles at which targets in support of the attack. This thesis presents a fast heuristic to predesignate TLAM target assignments to ships and submarines in multiple battle groups and launch areas over successive time periods. The heuristic allows tasks to be spread or restricted among firing units on a per-target basis, incorporates a variety of task types, and allows all or part of the target list to be manually prioritized. Additionally, the heuristic ensures that better solutions cannot be obtained through a simple, one-complement interchange.

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

**KEYWORDS:** Tomahawk Land-Attack Missile, Heuristic, Weapons Allocation

### **SOLVING DYNAMIC BATTLESPACE MOVEMENT PROBLEMS USING DYNAMIC DISTRIBUTED COMPUTER NETWORKS**

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**B.S.E., Princeton University, 1989**

**Master of Science in Operations Research-June 2000**

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**Second Reader: Arnold H. Buss, Department of Operations Research**

This thesis develops an architecture for dynamic distributed military operations research. This architecture assumes that a network of heterogeneous computing devices connects forces throughout the battlespace. Both the raw data about the battlespace and the operations research models used to analyze this data are accessible to devices on this network. The thesis designs a system using this architecture that invokes operations research network optimization algorithms to solve problems involving movement of people and equipment over dynamic road networks. A specific application is implemented to help a medic find the nearest aid station using a shortest path algorithm. This application marshals the most current data on unit locations and road conditions (distributed across the computing network) and locates on the network an appropriate algorithm that is then used to construct a solution. The answer is returned to the user as a web page in a form appropriate for his computing device. The application is implemented with existing technologies including the Java computer language, König, a Java-based tool for representing networks and graphs, and Hypertext Markup Language, a format for shared information on the Internet. This system uses operations research tools to transform data into decisions in real-time or near real-time.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software

**KEYWORDS:** Computer Architecture, Network Optimization, Java, Loosely Coupled Components

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## A MULTIVARIATE TIME SERIES ANALYSIS OF U.S. ARMY RECRUITING

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Master of Science in Operations Research-June 2000

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

The United States Army Recruiting Command requires tools to quantify the impact of factors in the recruiting environment, identify differences in the recruiting processes across its five regional subordinate units, and measure the effectiveness of its policies and resource expenditures. This thesis examines recruiting data for the “high-quality” male demographic from July 1992 to September 1997. It uses multivariate time series analysis to predict the number of enlistment contracts signed in a month as a function of fifteen exogenous and endogenous factors plus monthly indicators. A stepwise recursion using bootstrap simulation is developed to identify significant factors in the multivariate time series. The significant factors in the reduced models are compared to those contained in models developed in previous studies. The models are also used to create nine-month projections of recruiting production, which are compared to known production figures from test set data to determine forecast accuracy. The results of this research support the intuition that the influential factors differ by region. The stepwise model reduction recursion using bootstrap simulation offers potential for further refinement and application.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORDS:** Time Series, Bootstrap, Recruiting, Operations Research

## USING NEURAL NETWORKS WITHIN THE LEAVES OF A CLASSIFICATION TREE

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

Classification trees and neural networks are widely used individually, yet little is known about the effect of combining these two techniques. Earlier work has shown that using  $k$ -nearest neighbor ( $k$ -NN) inside the leaves of a tree can increase classification accuracy. Since neural networks are so powerful, we apply neural networks instead of the  $k$ -NN method inside the leaves of the tree.

This thesis studies the performance of this composite classifier. It is compared to the tree-structured classifier and the neural network classifier. We use commonly available data sets in this application and compare the results to those generated by other generally used classifiers.

Compared to the results of the other two classifiers in this thesis, the composite classifier always gives the lowest cross-validated misclassification error rates in these data sets. Its excellent performance tells us that it is worth further investigation.

**DoD KEY TECHNOLOGY AREA:** Other (Statistics)

**KEYWORDS:** Classification Tree, Neural Networks, Nnet.in.leaf Method, Cross-validation, Misclassification Rate

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### SERVICE LEVEL OPTIMIZATION FOR THE MARINE CORPS INSTITUTE

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**B.S., United States Naval Academy, 1993**

**Master of Science in Operations Research-June 2000**

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The Marine Corps Institute (MCI) is the distance learning center for the United States Marine Corps. MCI's mission is to develop, publish, distribute, and administer distance training and education materials to enhance, support, or develop required skills and knowledge of Marines. It also satisfies other training and education requirements as identified by the Commanding General, Marine Corps Combat Development Command.

To meet this mission MCI develops and assembles course materials ranging from simple training courses to college level Professional Military Education (PME) programs. Each course or program consists of multiple components that must be printed, stocked, and distributed to all Marines. Currently MCI offers 151 courses comprised of 305 printed components. In 1999 MCI processed over 550,000 requests for course materials.

In late 1998 MCI recognized the need to improve their inventory control processes. They desired a means of determining reorder points and reorder quantities for the Marine Corps Institute in order to improve service to Marines in the field. This thesis develops a non-linear program inventory model that minimizes the number of shortages per year, and returns reorder points and reorder quantities, thereby improving MCI's service to the Marine Corps.

**DoD KEY TECHNOLOGY AREA:** Other (Inventory Policy, Optimization)

**KEYWORDS:** Marine Corps Institute, Inventory Policy, Optimization

### HUMAN FACTORS ANALYSIS OF FISCAL YEAR 90 TO 97 ROTARY WING AND TACAIR FLIGHT MISHAPS

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**B.S., Florida State University, 1992**

**Master of Science in Operations Research-June 2000**

**Advisor: CDR John K. Schmidt, USN, School of Aviation Safety**

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

Human error is present in approximately 60 to 80 percent of all Naval Aviation (NA) flight mishaps (FMs). This indicates a need to identify the patterns and relationships of human error associated with NA FMs in order to develop tailored intervention strategies. This study uses the Human Factors Analysis and Classification System (HFACS), a human error oriented accident investigation and analysis process, to conduct post-hoc analysis of 77 rotary wing and 141 Tactical Aircraft (TACAIR) Class A and B human error FMs from Fiscal Year 90 to 97. This study indicates that Skill-Based Error, Decision Error, Adverse Mental State (AMS) and Crew Resource Management (CRM) are the predominant human error types associated with NA FMs. A nonparametric bootstrap simulation is performed for singular and combinations of human error types to develop the most effective intervention strategies. For the rotary wing community, the CRM human error type represents the best target for selected intervention strategies and potential cost savings. The AMS human error type provides the best target for selected intervention strategies and potential cost savings for the TACAIR community. The use of flight simulators is viewed as the most effective intervention strategy for both predominant human error types identified.

**DoD KEY TECHNOLOGY AREAS:** Air Vehicles, Manpower, Personnel and Training, Modeling and Simulation, Other (Accident Analysis)

**KEYWORDS:** Naval Rotary Wing Mishaps, Naval Tactical Aircraft Mishaps, Human Factors, Human Error, Accident Classification, Accident Prediction, Poisson Process, Modeling, Simulation, Accident Analysis

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### CAMPAIGN ANALYSIS OF A NATO GROUND FORCES CAMPAIGN IN KOSOVO

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Master of Science in Operations Research-June 2000

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James G. Taylor, Department of Operations Research

Second Reader: LCDR Douglas J. MacKinnon, USN, Department of Operations Research

On March 24, 1999, the North Atlantic Treaty Organization (NATO) started an air campaign by attacking targets in Serbia, including Kosovo. This thesis analyzes the question: "What might have happened if Serbia had not retreated and NATO had to conduct a ground forces campaign to achieve its objectives?"

The aggregated combat model uses the situational force scoring (SFS) methodology, introduced by RAND, to compute force ratio, attrition, and movement as the result of combat. For a portion of the campaign analysis, the General Campaign Analysis Model (GCAM<sup>TM</sup>), developed by *Systems Planning and Analysis, Inc.*, is used.

It is shown that a NATO ground forces campaign in Kosovo will only be successful, if tactical and technological measures can reduce significantly the defender's use of anti-tank (AT) weapons; even then, the casualties on the attacker's side are relatively high. Furthermore, the developed model is a starting point for the development of a decision support tool for joint contingency planning in higher HQ.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Campaign Analysis, Ground Forces, Kosovo/Serbia/Yugoslavia, RAND, Situational Force Scoring (SFS) Methodology, GCAM<sup>TM</sup>

### COMPARISON STUDY OF JANUS AND HLA WARRIOR

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Master of Science in Operations Research-June 2000

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Second Reader: MAJ Gerald M. Pearman, USA, TRADOC Analysis Center-Monterey

The Training & Doctrine Command (TRADOC) Analysis Center (TRAC) – Monterey, California re-engineered the Janus simulation as a technology demonstration. The completed simulation, HLA Warrior, applied modern technologies including an object-oriented design and state-of-art user interfaces. The project also re-wrote Janus source code in C++. The purpose of this thesis was to assess HLA Warrior's fidelity, defined as its ability to replicate Janus results, by conducting a statistical comparison of Janus and HLA Warrior. Given that Janus has high "face-validity," Janus results acted as the baseline from which HLA Warrior results were compared. The comparison involved executing identical scenarios in Janus and HLA Warrior, gathering results, and conducting a rigorous statistical comparison of Janus and HLA Warrior results. Statistical tests included the paired *t*-test and non-parametric Wilcoxon Signed Ranks Test.

Results from the tests showed differences between Janus and HLA Warrior. Investigation into the causes of the differences found two source code errors in HLA Warrior. Re-evaluation of HLA Warrior following correction of the errors resulted in a reduction in magnitude of the differences. Probable causes due to algorithm implementation differences were also identified. While differences exist, HLA Warrior appears to have face-validity and generally produces outcomes similar to Janus.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Janus, HLA Warrior, Statistical Validation, Simulation

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### **WHO RESPONDS AND HOW LONG DOES IT TAKE: ASSIGNING FIRE STATION AREAS OF RESPONSIBILITY**

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B.S., United States Naval Academy, 1983  
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**Master of Science in Operations Research-June 2000**

**Advisor: Robert F. Dell, Department of Operations Research**

**Second Reader: R. Kevin Wood, Department of Operations Research**

The city of Monterey, California, provides fire protection and emergency medical response (FP&EMR) for the city of Monterey, an Army facility and two adjoining communities. The city currently maintains three full-time fire stations. Within the city's boundaries lies the U.S. Naval Postgraduate School (NPS), which currently provides its own FP&EMR, but the city is evaluating the possibility of providing this service for NPS. This thesis develops models to predict response times from NPS and city stations to emergency locations and combines these models with an optimization model to evaluate how optimal response times would vary with and without the NPS station. Results indicate that the city would marginally satisfy federal response-time requirements for NPS by operating only its current three stations: Average response is acceptable, but the variance is not. However, if the city operates the NPS station and only two of its current stations, estimated response times improve over the status quo, and variance is acceptable. Based on data for one year, city operation of all four stations would provide a 7.5% reduction in total estimated response time compared to the status quo, while using two stations plus the NPS station would provide a 4.9% reduction.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Optimization, Integer Linear Program, P-Median Model

### **PROTECTING THE FORCE: APPLICATION OF STATISTICAL PROCESS CONTROL FOR FORCE PROTECTION IN BOSNIA**

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**Master of Science in Operations Research-June 2000**

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**Second Reader: Thomas W. Lucas, Department of Operations Research**

Military commanders determine the appropriate Force Protection measures to protect their units from a wide variety of threats based on their assessment of the enemy threat in the specific situation. They currently have no statistical tool from which to base their assessment of the threat, or to recognize changes in the current situation. In Operations Other Than War (OOTW), environments where the enemy is disorganized and incapable of mounting a deception plan, staffs could model hostile events as stochastic events and use statistical methods to detect changes to the process. This thesis developed a statistical tool, based on Cumulative Sum (CUSUM) and Shewhart Charts, that military leaders can use in OOTW environments to recognize statistically significant changes in the situation. The tool applies current univariate control chart methods, as well as an original nonparametric multivariate control scheme developed in this thesis, to North Atlantic Treaty Organization (NATO) Stabilization Force (SFOR) incident data. The tool enables commanders to identify isolated and persistent shifts in the means of the data categories or shifts in the correlation of three data categories. By recognizing changes in the current situation, military leaders have a basis from which to change their force protection measures and better protect their unit.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software, Other (Force Protection)

**KEYWORDS:** Statistical Process Control, Multivariate, Force Protection

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### MODELING AND ANALYSIS OF HUMAN ERROR IN NAVAL AVIATION MAINTENANCE-RELATED MISHAPS

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Master of Science in Operations Research-June 2000

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Second Reader: Samuel E. Buttrey, Department of Operations Research

This study investigates human error associated with 599 Naval Aviation maintenance-related mishaps (MRMs) in Fiscal Years 90-99. The Human Factors Analysis and Classification System Maintenance Extension (HFACS-ME) taxonomy was utilized to classify contributory human errors within a robust theoretical framework. Variable Poisson process models are developed to predict MRMs and relationships between the error dimensions are investigated. The results of this study show that the HFACS-ME taxonomy provides an adequate framework for the classification of MRM causal factors; that variable Poisson process models are suitable for predicting future mishaps; and that there are significant relationships between selected causal dimensions; sufficient to warrant further investigation. These results provide information regarding the predicted impact of MRMs on future operational readiness and mission capability. Through being aware of these aspects, decision-makers are armed with the knowledge to make better decisions concerning the preservation and allocation of the resources at their disposal.

**DoD KEY TECHNOLOGY AREAS:** Air Vehicles, Manpower, Personnel, and Training, Modeling and Simulation, Other (Aviation Safety)

**KEYWORDS:** Aviation Accidents, Aviation Mishaps, Accident Classification, Accident Prediction, Maintenance Mishaps, Maintenance Error, Human Factors, Human Error, Poisson Process, Naval Aviation, Trend Analysis

### ENUMERATING NEAR-MINIMUM CUTS IN A NETWORK

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Master of Science in Operations Research-June 2000

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Second Reader: Gerald G. Brown, Department of Operations Research

We describe an algorithm for enumerating near-minimum-capacity cuts in weighted or unweighted, directed or undirected networks with applications to network interdiction. The algorithm begins by finding a minimum (capacity) cut and then recursively considers potential solutions that include or exclude arcs in that cut. Feasibility is evaluated by solving incremental maximum flow problems at each node of the enumeration tree. Backtracking occurs when the maximum flow, i.e., minimum cut capacity, exceeds a user-specified threshold or inconsistencies are discovered with respect to the included and/or excluded arcs. The algorithm is programmed in Java (JDK 1.2.2) and run on a 500 MHz Pentium personal computer with 96 megabytes of memory. As an example of computational performance, all 6 minimum cardinality cuts are enumerated in .06 seconds for a grid network with 51 nodes and 140 arcs while solving 44 incremental maximum flow problems. All 66 cuts of minimum cardinality, or minimum cardinality plus one, are enumerated in 900 seconds for the same network while solving 653,222 incremental maximum flow problems.

**DoD KEY TECHNOLOGY AREA:** Other (Network Interdiction)

**KEYWORDS:** Network Interdiction

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### AN EVALUATION OF THE AVIATION MAINTENANCE CLIMATE ASSESSMENT SURVEY (MCAS) APPLIED TO THE 3RD MARINE AIR WING

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Faced with aging aircraft and fewer acquisitions, Naval Aviation has redoubled its effort to preserve assets through preventive maintenance and reduction of aircraft mishaps. Eighty percent of all mishaps are due in part to human error, and approximately one out of five major mishaps are due to maintainer, line, or facility related factors. Among various efforts to systematically reduce mishaps is the use of the Maintenance Climate Assessment Survey (MCAS). This survey is designed to capture maintainer perceptions of safety. This thesis analyzes the results of 977 responses to MCAS given to the 3<sup>rd</sup> Marine Air Wing (MAW) maintenance personnel. In addition, it explores the MCAS's relationship with human errors present in 21 maintenance-related incidents (MRIs) using the Human Factors Analysis and Classification System - Maintenance Extension. This analysis finds statistically different responses among the squadrons of the 3<sup>rd</sup> MAW to the MCAS. These differences show the MCAS can detect variations between aviation units and associated Model of Organization Safety Effectiveness components. While no significant correlation between the nine adequately surveyed squadrons and their MRIs is found, a content analysis of the MCAS shows there is a relationship between the MRIs a squadron experiences and the items of the six MOSE components.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Manpower, Personnel, and Training

**KEYWORDS:** Safety Climate, Maintenance, Human Factors, Human Error, High Reliability Organizations, Safety Culture, Naval Aviation

### HUMAN FACTORS ANALYSIS OF U.S. NAVY AFLOAT HAZARDOUS MATERIAL MISHAPS

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Master of Science in Operations Research-June 2000

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

Personnel aboard U.S. Naval vessels face risk of occupational injury and illness. A substantial part of that risk involves incidents, or cases of exposure to hazardous materials (HAZMAT). Due to the nature of this type of risk, there are many opportunities to improve safety and readiness and to reduce the number of workdays lost to injury. For the period from CY94 – CY98 there were 627 HAZMAT mishaps involving 820 personnel onboard U. S. Navy surface ships. HAZMAT root causal factors were identified through the evaluation of Special Case Mishap Reports maintained by the Naval Safety Center; 89% of these mishaps were attributable to human error. Failure to use personal protective equipment (30.0%) and failure to recognize a hazardous situation (24.6%) were the primary reasons given for the mishaps. Comparisons were made between HAZMAT, electrical shock and back injury mishaps. While minor differences exist between these types of mishaps, overall there were many commonalities that may be observed. Most are relatively minor as classified by severity, occur aboard Carriers, and involve personnel in the E-3 to E-5 rank range.

**DoD KEY TECHNOLOGY AREAS:** Biomedical, Human Systems Interface, Manpower, Personnel, and Training

**KEYWORDS:** Maritime Mishaps, Hazardous Material, Accident Analysis, Human Factors, Human Error, Poisson Process

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### **GRAPHIC USER INTERFACE DESIGN FOR MAPPING, INFORMATION, DISPLAY, AND ANALYSIS SYSTEMS**

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B.S., United States Naval Academy, 1993**

**Master of Science in Operations Research-June 2000**

**Advisors: William K. Krebs, Department of Operations Research**

**Gordon H. Bradley, Department of Operations Research**

**Second Reader: Rudolph P. Darken, Department of Computer Science**

This thesis evaluates both the interface design process and the map-based mission planning tools of the Loosely Coupled Components Research Group, Naval Postgraduate School for human factors usability. After identifying flaws in the process and usability problems in the interface designs, a new software design process and map-based mission-planning tool are developed. A usability study was conducted on the new mission-planning tool, determining it to be a usable product while establishing baseline data for future interface improvements. The map-based mission-planning tool, written in the Java programming language, is called the Mapping, Information, Display, and Analysis System (MIDAS). In its Beta form, MIDAS can display any geo-referenced map or image and allow users to annotate it with several graphical tools. Future versions will incorporate existing map-based decision-aiding tools such as optimal track routing, intelligence image rubber-sheeting, and wirelessly networked unit tracking. This thesis recommends the incorporation of human factors early in the software design process and quality usability studies on interfaces to ensure a usable product.

**DoD KEY TECHNOLOGY AREAS:** Battle Space Environments, Command, Control, and Communications, Computing and Software, Human Systems Interface

**KEYWORDS:** Joint Vision 2010, Information Superiority, Battlespace Dominance, Java, Map, Mission Planning, Land Warrior, Command Post of the Future, Graphic User Interface, Human Computer Interaction, Usability Study, Loosely Coupled Components

### **AN EVALUATION OF THE HYDRA-7 COUNTERMINE WEAPON SYSTEM**

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**B.S., Texas A&M University, 1988**

**Master of Science in Operations Research-June 2000**

**Advisor: James N. Eagle, Department of Operations Research**

**Second Reader: William G. Kemple, Command, Control, Communications, Computers, and Intelligence Academic Group**

The basic principle of Maneuver Warfare in the 21<sup>st</sup> century is the seamless integration of sea and land as maneuver space. Unfortunately, our inability to conduct counter-mine and counter-obstacle operations in the littorals severely curtails our ability to conduct Amphibious Warfare, a key ingredient to maneuver. Hydra-7, a possible solution to this problem, is one of the most promising counter-mine weapons under development, but its final performance level will depend on the effectiveness of sub-component technologies. These sub-component technologies have yet to reach maturity and may not perform as well as desired. This thesis provides analysis procedures and models to predict Hydra-7 effectiveness for a broad range of possible performance values of sub-component systems. The methodology will determine which of the sub-component technologies is most critical to the final performance of Hydra-7.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Simulation, Parameterization, Sensitivity Analysis

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### RANGER AIR LOAD PLANNER

**Maximo A. Moore, III-Captain, United States Army**

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**Advisor: Gordon H. Bradley, Department of Operations Research**

**Second Reader: Gerald G. Brown, Department of Operations Research**

The United States Army 75<sup>th</sup> Ranger Regiment conducts combat parachute operations as part of United States Special Operations Command (USSOCOM). The Rangers are the largest deployable asset of USSOCOM, and are required to plan and execute large-scale parachute assaults into hostile theaters with little or no notice. Generally fighting numerically superior enemy, far from the support of the conventional Army, Rangers must arrive capable of self-sustaining combat operations in any operational environment. This thesis provides Ranger air load planners a tool to rapidly plan feasible mission equipment loads. The Ranger Air Load Planner (RAP) is simple to learn and operate, provides load plans selected from pre-approved, United States Air Force load templates, and supports dynamic decision support with rapid solution response. An optimization model is used in the thesis to objectively assess the quality of RAP load plans. RAP is a working product that can be adapted for use in air load mission planning by all units under USSOCOM.

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

**KEYWORDS:** Mission Planning, Analysis, Special Operations, MPARE, Java, Loosely Coupled Components

### OPTIMIZING PROCUREMENT OF SPECIAL OPERATIONS WEAPONS AND EQUIPMENT

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**Master of Science in Operations Research-June 2000**

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The Joint Operational Stock (JOS) is a centrally-located inventory of Special-Operations peculiar weapons and equipment, managed by the United States Special Operations Command (USSOCOM). New procurement of JOS weapons and equipment is currently planned by manually prioritizing the item-wise shortfalls experienced in the JOS inventory during the previous year. This method has not always provided convincing justification for funding, as indicated by the loss of such funding in fiscal year 1999. Also, new technology and other items not historically demanded must be handled in an ad-hoc fashion. We introduce a procurement planning tool that seeks to maximize the ability to completely loadout special operations missions by coordinating year-by-year procurement of individual items. Rather than focus just on history, concentration is on supporting future missions over an entire multi-year planning horizon. The plans are quickly suggested by a simple greedy myopic heuristic shown to produce almost-optimal advice.

**DoD KEY TECHNOLOGY AREA:** Other (Weapons and Equipment Procurement)

**KEYWORDS:** Logistics, Special Operations Forces, Joint Operational Stock, Optimization, Heuristic, Inventory, U.S. Special Operations Command

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## OPERATIONS RESEARCH

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### **DETERMINANTS OF FLIGHT TRAINING PERFORMANCE: AN ANALYSIS OF THE IMPACT OF UNDERGRADUATE ACADEMIC BACKGROUND**

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This thesis uses pre-commissioning academic and demographic factors, along with flight school performance data to measure pilot success in flight school. The goal is to determine if undergraduate major or school attended affect flight school performance. Measures of effectiveness include: (1) Flight School Completion Status, (2) Aviation Pre-Flight Indoctrination Composite Scores, and (3) Primary Flight Training Composite Scores. Recruitment for naval aviators is focused on individuals with “technical majors,” according to present policy of the Naval Recruiting Command. This recruiting philosophy is based on the “Rickover Hypothesis,” which postulates that naval officers with technical degrees are superior to naval officers with non-technical degrees. The Logit model showed that aviators with engineering degrees have a statistically greater chance of completing flight school than aviators with non-engineering technical or non-technical degrees. In addition, the results showed an association between academic background and flight school performance. This research justifies the current Navy policy of concentrating aviator recruitment efforts on individuals with technical degrees.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORDS:** Aviator Selection, Aviation Flight Training, Classification and Regression Trees, CART, Cross-Validation, Tree, Logistic Regression, Logit

### **STATISTICAL ANALYSIS OF THE NAVAL INVENTORY CONTROL POINT REPAIR TURN-AROUND TIME FORECAST MODEL**

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Accurate forecasting of repair turn-around time (RTAT) of United States Navy depot level repairable items is critical to achieving optimal service levels while minimizing procurement and repair costs. The Navy’s Inventory Control Point has developed a forecast model that uses sophisticated Statistical Process Control techniques and non-parametric algorithms to forecast RTAT. This thesis attempts to validate the Navy’s RTAT forecast model by comparing its performance to those of simple time series forecasting methods. It was found that the assumptions implicit in the UICP RTAT forecast model have a significant impact on forecast accuracy. In addition to documenting these model properties, a goal of this thesis is to identify variables that the UICP model does not use in RTAT forecasting which may improve its accuracy. The research focuses on data for repairable items that have high dollar value and the greatest number of repair transactions per quarter.

Results show that the Navy’s model is not consistently more accurate than any of the alternative techniques examined, and that it tends to ignore many large RTAT observations, causing it to under-forecast RTAT. Thesis research also reveals that accounting for differences in disparate designated overhaul points may significantly improve the prediction of RTAT. Finally it is shown that additional variables, derived from a NAVICP Philadelphia database and designed to capture the queueing aspect of the repair process, may significantly improve the prediction of RTAT. These findings point to the use of queueing information to obtain more accurate RTAT forecasts.

**DoD KEY TECHNOLOGY AREA:** Other (Inventory, Forecasting)

**KEYWORDS:** Forecasting, Statistics, Repairable, Inventory, Operations Research

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## OPERATIONS RESEARCH

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### OPTIMAL POSITIONING OF NAVAL PRECISION GUIDED MUNITIONS

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The Department of Defense (DoD) Report to Congress, *Kosovo/Operation Allied Force After-action Report*, listed the pre-positioning of precision guided munitions (PGM) as a leading force sustainment concern. The high utilization of PGMs in recent smaller-scale contingency operations (SSCs) such as *Operation Allied Force* has led DoD to examine the PGM pre-positioning policy. Current doctrine positions PGMs per the possible conflicts detailed in the Defense Planning Guidance (DPG). Currently, the DPG only addresses the two nearly simultaneous major theater wars (MTWs). Although PGM expenditures during SSCs may deplete a significant portion of pre-positioned stocks, they are not considered when planning the pre-positioning of PGMs. Additionally, when PGM stocks are depleted while conducting SSCs, the decrease in overall military readiness may adversely affect the operational commanders' ability to conduct MTWs in their areas of responsibility. The purpose of this thesis is to develop a method to optimally plan the positioning of PGMs for SSCs and the DPG designated MTWs.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Logistics, Ordnance, Optimization

### THE FLAMING DATUM PROBLEM WITH VARYING SPEED

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**Master of Science in Operations Research-June 2000**

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The problem of detecting an enemy submarine whose possible position was revealed by the hit of a torpedo is known as the "Flaming Datum" problem. All previous studies devoted to this theme make unrealistic assumptions about the speed of the escaping target when dealing with a diesel-electric submarine. In this kind of submarine the constraint imposed by the remaining charge of its batteries determines that its behavior is essentially conservative in how fast it should escape.

The objective of this thesis is to explore the idea of varying speed in the flaming datum problem. Two different approaches are considered. An analytical model is developed based on the relationship among some of the physical factors that could determine or constrain the behavior of a diesel submarine while escaping from the area of the flaming datum. The second approach considers a discrete event simulation using the Java-based Simkit package. Data analysis is used to determine a possible fit for the simulation results. Several tactics are explored to determine their effects on detection probability.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles, Modeling and Simulation, Other (Search and Detection)

**KEYWORDS:** Unit Circle, Detection Rate, Edge, Farthest on Circle (FOC), Maximum Possible Distance (MPD)

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## OPERATIONS RESEARCH

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### **AIM-7 SPARROW MK-58 ROCKET MOTOR RELIABILITY AND LIFE DATA ANALYSIS**

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The AIM-7 Sparrow missile is a radar-guided, air-to-air missile that is widely deployed and used by U.S. and NATO (North Atlantic Treaty Organization) forces. Due to recent catastrophic failures of the MK-58 rocket motor, the future of the AIM-7 Sparrow is uncertain as it approaches the end of its predicted service life of twenty years. A large number of AIM-7 Sparrows are currently in the inventory of the United States and NATO.

The catastrophic failure of a MK-58 rocket motor could result in loss of life, loss of aircraft, and/or an unsuccessful mission. This thesis analyzes the existing catastrophic failure data of the AIM-7 Sparrow to develop a reliability model of the MK-58 rocket motor as a function of the motor's age using the Weibull distribution. The model parameters were obtained using both maximum likelihood estimators (MLE) and Bayesian methods.

The model can be used to determine the expected useful life of the MK-58 rocket motor based on risk and mission. The model also assists in providing a timeframe for the development, procurement, and replacement for the AIM-7 Sparrow with another air-to-air missile system.

**DoD KEY TECHNOLOGY AREA:** Conventional Weapons

**KEYWORDS:** Reliability, MK-58 Rocket Motor, Air-to-Air Missiles, Sparrow, AIM-7, Bayesian, MLE

### **EVALUATING DEMOGRAPHIC ITEM RELATIONSHIPS WITH SURVEY RESPONSES ON THE MAINTENANCE CLIMATE ASSESSMENT SURVEY (MCAS)**

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The Maintenance Climate Assessment Survey (MCAS) was developed to proactively assess factors that contribute to a high reliability organization and strong safety climate. The 3<sup>rd</sup> Marine Air Wing (MAW), which was seeking to proactively improve its safety posture requested the assistance of the School of Aviation Safety at the Naval Postgraduate School to examine its safety climate. Previous studies of the MCAS instrument have focused on the items and their relationship to the HRO based model of safety effectiveness components: process auditing, reward system, quality assurance, risk management, command and control, and communication/functional relationships. The present effort is the first attempt to consider the relationship between item component responses and demographic item responses. It evaluates 893 maintainer responses to the MCAS from 3<sup>rd</sup> MAW and looks for measurable effects due to demographics. This study finds that the regression models constructed using the demographics as explanatory variables have very little utility in predicting scores for the components. This result allows planners the relief of using the demographics as a low priority issue.

**DoD KEY TECHNOLOGY AREAS:** Manpower, Personnel, and Training, Other (Aviation Safety)

**KEYWORDS:** Human Factors, Human Error, Accident Classification, High Reliability Organizations, Corporate Safety Culture, Naval Aviation

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## OPERATIONS RESEARCH

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### OPTIMAL ALLOCATION OF SELECTED T-SERIES ADVANCED BASE FUNCTIONAL COMPONENT EQUIPMENT PACKAGES

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Master of Science in Operations Research-June 2000

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Advanced Base Functional Components (ABFCs) are pre-planned modular units of equipment and personnel designed to extend or create the logistic infrastructure required to support naval expeditionary operations. The ABFC program is structured to combine trained personnel with the equipment needed to perform a particular logistic mission such as seaport operations and cargo handling, warehousing, or freight terminal operations. If the ABFC must deploy to a theater of operations, individual equipment packages containing material handling equipment and/or civil engineering support equipment (CESE) vehicles tailored to the operational situation are required.

This thesis presents an optimization model that determines the minimum number and type of ABFC equipment packages required for the land-based naval logistic requirements of several hypothetical scenarios, some of which illustrate dual major theater war scenarios. The model quickly and efficiently provides the user with the minimum required number of material handling equipment and CESE vehicles for selected T-series ABFCs.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Operational Logistics, Advanced Base Functional Components, ABFCs, ABFC Equipment Packages, Integer Linear Programming

### AN INFINITE HORIZON ARMY MANPOWER PLANNING MODEL

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Master of Science in Operations Research-June 2000

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The Army must decide on the number of officers to access, promote, and, when necessary, separate each year. This thesis develops the Infinite Horizon Manpower Planning model (IHMP), an optimization model (based on convex quadratic programming), for managing officers in the Army Competitive Category. IHMP determines the annual numbers of accessions, promotions, and separations that best meet the desired inventory targets. In addition to operational and policy constraints, IHMP incorporates the recently implemented Officer Professional Management System XXI. Because one cannot imagine a day when the Army is not needed, the thesis regards personnel management as an infinite horizon planning problem and considers several techniques to approximate infinite time. Results from IHMP help analyze two personnel issues hypothesized by Army analysts. In one case, the Army requires the number of majors in the Operations career field to be at least 95% of its target and IHMP results indicate the number of majors in other career fields are short of their targets by as much as 30%. For the other case, IHMP outputs indicate that current inventory targets are not well aligned for a 16% reduction to the overall number of officers. IHMP analyses show how to align these inventory targets for the reduced number of officers.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORDS:** Manpower Planning, Optimization, Approximation

