MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

THE ROLE OF COLOR AND FALSE COLOR IN OBJECT RECOGNITION WITH DEGRADED AND NON-DEGRADED IMAGES

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Recent technological advances in the design and manufacturing of night vision multispectral sensors now allow spatially registered imagery provided by each of the sensors to be combined within a single fused image for display to an end user. The product is a multispectral false-colored rendering of the imaged scene. The use of false color in fused imagery may facilitate object recongnition, providing contour information of the objects present in the scene, but incongruently colored fused imagery may be disruptive of perceptual performance. This study investigated if the use of false color imagery compared to natural color imagery was helpful or not in object recognition. Subjects' reaction times (RTs) and error rates were measured in a standard naming task. Stimuli consisted of photographs of food objects that had been manipulated in color (natural color, false color, natural grayscale, and false grayscale) and noise (three levels). The results of the experiment showed similar differences in RTs between color images (natural or false) and their grayscale counterparts at different levels of noise, indicating that both color conditions were similarly helpful in object recognition. These results give an indication that false color may be useful in multispectral sensors based on its facilitation of image segmentation with shape degraded images.

DoD KEY TECHNOLOGY AREA: Human Systems Interface

KEYWORDS: Human Systems Interface, Sensors, Sensor Fusion, Target Recognition

EFFECTS OF BIOLOGICAL WARFARE ON THROUGHPUT AT SEAPORTS OF DEBARKATION DURING A MAJOR THEATER WAR

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Deterministic and stochastic optimization models are developed to study how a biological weapons attack upon a Seaport of Debarkation (SPOD) supporting a Major Theater War can disrupt the force build-up required to support that war. The models are exercised with a wide range of estimates for decontamination time, daily recovery ability and maximum recovery level to explore the importance of these values to timely force build-up. Uncertainty in the timing of attacks is handled in two ways: (*i*) a deterministic model is solved under optimistic and pessimistic conditions to provide lower and upper bounds on "force disruption," and (*ii*) a stochastic model is solved to minimize expected disruption across several potential

attack scenarios. Force disruption measures lateness of cargo deliveries plus non-deliveries. Results indicate that force build-up is most affected by the time required to decontaminate the SPOD following a biological attack. For most model runs, a decontamination time of up to ten days causes only minor disruptions to force build-up. A comparison of results from the stochastic and deterministic models indicates, that even with very limited intelligence, the stochastic model can mitigate against the effects of future biological attacks and force build-up may be significantly improved.

DoD KEY TECHNOLOGY AREA: Chemical and Biological Defense

KEYWORDS: Optimization, Stochastic Optimization, Biological Warfare

EFFECTIVENESS ANALYSIS OF EA-6B SUPPORT JAMMING WITH A DISTRIBUTED NETWORK OF ELECTRONIC WARFARE-CAPABLE UNMANNED AERIAL VEHICLES (U)

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The Navy's EA-6B Prowler is the only active support-jamming platform in the Joint Force aircraft inventory, and with the third-generation improved capability (ICAP-III) upgrades, the Prowler is slated to be operational until the year 2015. The 2015 projection may be optimistic, but EA-6B follow-on technology is not currently defined. The objective of this thesis is to determine the improvement in jamming effectiveness with a hybrid mix of ICAP-III EA-6Bs operating with a distributed network of EW-capable unmanned aerial vehicles (UAVs). The primary measure of effectiveness is the ratio of the amount of time the strike package is detectable by acquisition radar under jamming conditions to the amount of time the strike package is detectable without the jamming protection. The order of battle is based on a projected Southwest Asian scenario for the year 2010 as published in the Joint Tactical Air Electronic Warfare Study (JTAEWS). This analysis is conducted in three phases representing real-world operational tasking. Phase 1 addresses how accurately each threat can be located as a function of ime. Phase 2 determines the optimal beamwidth to employ against each of the threat radar, given location accuracy determined in Phase 1. Applying the results of optimal beamwidth analysis, Phase 3 determines the jamming effectiveness of the hybrid network in terms of protection provided to the strike package using the CONtour RADar (CONRAD) model. The results can be used to assess the practicality of extending the expected service life of the EA-6B through 2015 using a distributed network. In addition, the distributed architecture, implementing currently available technology, can ease the transition to follow-on technology and, as such, should be considered as one possible alternative to the EA-6B follow-on.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Sensors, Modeling and Simulation

KEYWORDS: EA-6B, Unmanned Aerial Vehicle (UAV), Support Jamming, Electronic Warfare

RE-OPTIMIZATION OF TIME-PHASED FORCE DEPLOYMENT PLANS IN RESPONSE TO EMERGENT CHANGES DURING DEPLOYMENT

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Although Operation Desert Storm has been heralded as a marvel in logistics, it was plagued with inefficiencies. Because of decreases in lift capacity since the Gulf War, and in anticipation of future operations that will likely evolve more rapidly, the U.S. needs better tools to develop efficient logistics plans.

The Warfighting and Logistics Technology Assessment Environment (WLTAE) developed by Johns Hopkins University Applied Physics Laboratory simulates the effects of logistical decisions on operational outcomes. WLTAE tracks the flow of units and materiel into ports in theater via a Time Phased Force Deployment Data List (TPFDDL) that remains fixed throughout the simulation, regardless of concurrent port damage. Responding to degradations of ports is an essential feature of robust planning, and requires continuous updates of the TPFDDL.

How to modify a TPFDDL and its planned flow of supplies into a theater to account for changes in port capabilities was shown. First, the flows of materiel in the TPFDDL are aggregated into notional ships by a ship-loading heuristic. Second, these notional ships are rescheduled as necessary to alternate ports and/or arrival dates by a ship reassignment heuristic. The solution quality of each heuristic is objectively assessed by comparison with a respective optimal solution to an equivalent mathematical programming model.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Optimization)

KEYWORDS: Logistics, Optimization, Ship Scheduling, Simulation, TPFDD

DETERMINING THE REQUIRED NUMBER OF COMBAT LOGISTICS FORCE SHIPS (U)

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This thesis provides the resources necessary to make informed decisions on the number of TADC(X) ships needed to support ordnance requirements in dual MTWs. The scenarios developed use General Campaign Analysis Model (GCAM) and are written in Condition Object Oriented Meta Language (COOML). Building upon previous studies concerning the number of TADC(X) ships, this thesis provides the decision maker the range of TADC(X) ships and demonstrates the impact that each additional TADC(X) ship will have upon CVBG ordnance sustainability.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Logistics, TADC(X), Analysis, GCAM, Major Theater War, Ordnance, Shuttle Ship

FACTORS AFFECTING CHRONICALLY SHORT MILITARY OCCUPATIONAL SKILL (MOS) SPECIALTIES IN USMC RESERVE UNITS

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Military Occupational Specialty (MOS) manning levels within Selective Marine Corps Reserve (SMCR) units are of interest to the U.S. Marine Corps (USMC) because of the impact shortages have on unit operational capabilities. The goals of this study are to: 1) identify chronically short MOSs in SMCR units; 2) explore demographic influences on SMCR manning levels; and 3) determine the influence of the Montgomery GI Bill (MGIB) Stipend on SMCR enlistment. The study determines chronically short MOSs using data from the Defense Manpower Data Center and finds MOS shortages are not confined to any particular MOS or geographic region. Using Census Bureau demographic data, the study develops a regression tree to predict demographic influences on regional SMCR unit MOS fill rates. The study identifies several demographic factors correlating to MOS fill rates at the region and state level. Finally, the study compares SMCR unit personnel populations and determines that differences exist in several areas. The USMC should target monetary educational incentives at the RUC level while developing alternative recruitment incentives since educational incentives alone may not produce the desired recruitment in chronically short MOSs in every SMCR unit.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Military Occupational Skill Specialties (MOS), USMC Reserve Units, Demographic Factors

MEASURING SURFACE COMBATANT FLEET EFFECTIVENESS

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How is the effectiveness of surface combatant ships in a Major Theater War (MTW) measured? While Measures of Effectiveness (MOE) for an individual ship can include its number of missiles, speed, and endurance, it is difficult to find a Measure of Effectiveness credible to experienced warplanners for a fleet of ships.

This thesis develops a Fleet Measure of Effectiveness (FMOE) to gauge the success of surface combatants in a Major Theater War (MTW). We define Fleet Measure of Effectiveness (FMOE), discuss the elements that contribute to its calculation, and justify why a distribution for FMOE is preferable to a point estimate. This thesis also shows how to integrate variable input data and human judgments into an optimization model. Finally, FMOE is implemented through case studies that examine the impact logistics support has on fleet effectiveness and show how FMOE distributions can be used to compare the effectiveness of various surface combatant fleets.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Surface Combatant Effectiveness

JOINT OPERATIONAL STOCKS INVENTORY PURCHASING PRIORITIZATION METHODOLOGY

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Joint Operational Stocks (JOS) are used as a "revolving" inventory of end-use items available for loans to United States Special Operations Forces. The JOS items are administered by the United States Special Operations Command (USSOCOM) in Tampa, FL. By using a revolving inventory, USSOCOM reduces the total quantities of items that need to be stocked. However, current stocks are inadequate to meet demand, and current funding is inadequate to fully stock all inventory items. Currently USSOCOM has no methodology to prioritize purchase decisions to provide the best support to Special Operations Forces, per dollar spent. This thesis provides a methodology to allocate limited financial resources in procuring additional JOS units of inventory to provide the greatest increase in mission support benefit to special operations forces. The methodology is applied to the current JOS inventory system, providing a recommended prioritized sequence of inventory purchases. This thesis is limited to those items in the JOS inventory that currently do not have adequate quantities to meet the current demand, yet have sufficient demand history to provide adequate data for analysis. The methodology developed, however, is generic in nature and can be applied again in the future as more data becomes available.

DoD KEY TECHNOLOGY AREA: Other (Inventory Systems)

KEYWORDS: Logistics, Special Operations Forces, Mission Usefulness, Marginal Analysis, Inventory

STOCHASTIC MODELING OF NAVAL UNMANNED AERIAL VEHICLE MISHAPS: ASSESSMENT OF POTENTIAL INTERVENTION STRATEGIES

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The employment of unmanned aerial vehicles (UAVs) in combat operations has demonstrated that UAVs can effectively provide surveillance, reconnaissance, and target acquisition support in place of manned aircraft. However, the Pioneer UAV, currently employed by the U.S. Navy and Marine Corps, has an unacceptable mishap rate. Half of the UAV mishaps are attributable in part to human factors causes. This points to a requirement for developing tailored intervention strategies. This study develops a stochastic simulation model of UAV mishaps to be used for the evaluation of human factor initiatives in terms of budgetary cost and mission readiness. It determines that electro-mechanically caused mishaps cost approximately the same as human factors mishaps. However, in comparison, human factors mishaps degrade mission readiness significantly. Intervention strategies need to address unsafe acts by the operator, unsafe conditions for flight operations, and unsafe supervision. The study recommends the following intervention measures: the use of system simulators; the implementation of improved aircrew coordination training; and the stabilization of personnel assignments.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Unmanned Aerial Vehicles, Human Factors, Mishap Causation, Mishap Intervention, Aerial Reconnaissance, Stochastic Modeling, Simulation

ASSESSMENT OF MAINTENANCE SAFETY CLIMATE IN U.S. NAVY FLEET LOGISTICS SUPPORT WING SQUADRONS

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Despite Naval Aviation's success in cutting its Class A Flight Mishap rate in half each successive decade between 1950 and 1990, the proportion of aircraft losses attributable to human error has remained relatively constant during the last decade. From Fiscal Years 1990 through 1998, maintenance error was a causal factor in approximately one out of every five Class A Flight Mishaps. Presently there is an on-going effort to identify and systematically reduce factors contributing to human error in Naval Aviation maintenance. This study administers Baker's (1998) Maintenance Climate Assessment Survey (MCAS), which evaluates factors contributing to high reliability, to nearly 1000 participants from the Naval Fleet Logistics Support Wing (FLSW). The purpose of this study is to assess maintainer perspectives of maintenance operations and safety culture within their respective communities. This study finds statistically differentiable responses among the aircraft communities that comprise the FLSW; differences that potentially will help in identifying and developing intervention strategies to further reduce human error in aviation maintenance. Additionally, a proposed list of MCAS questions is produced for fleet wide distribution.

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

ANALYZING SUCCESS OF NAVY ENLISTEES WITH MORAL WAIVERS

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Unsuitable attrition of recruits from the Navy is a costly problem. This thesis compares unsuitable attrition rates for recruits with moral waivers to the rates of recruits without moral waivers. Unsuitable attrition is also modeled using both logistic regression and classification trees for the recruits who received moral waivers. The comparison and models were completed on two data sets, one that contained all recruits for FYs 95-96 and a subset of the data modified to account for a known bias in the data. The comparison of unsuitable attrition rates found that recruits with moral waivers do have a significantly higher rate of unsuitable attrition than that of recruits without moral waivers. The prediction models produce "significant" variables, but they predict poorly when applied to the data. However, it is found that recruits who are not high school graduates and receive a moral waiver are the most likely unsuitable attrition losses. Unsuitable attrition rates differ when the data collection error is addressed, but both data sets result in the same conclusion that recruits with moral waivers have a higher unsuitable attrition rate than recruits without moral waivers.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Unsuitability Attrition, Moral Waivers, Recruiting, Logistic Regression, Classification Tree

IMPROVED QUESTIONNAIRE DATA HANDLING AND AUTOMATED ANALYSIS CAPABILITIES FOR THE MV-22 OPERATIONAL EVALUATION

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This thesis investigates the method by which the V-22 Multiservice Operational Test Team (MOTT) collects and analyzes subjective operational test data, and suggests improvements to the tools currently in use. The MOTT uses a Microsoft Access custom application to generate and administer questionnaires and report summary results of the data collected. Using Visual Basic for Applications to implement Automation techniques, specific program improvements are created and implemented that use basic summary statistics to assist in handling the problems of excessive questionnaire lengths and user-friendly summary report generation. A trend analysis is conducted on data from a previous operational assessment in terms of MOTT pilot demographics to highlight any response biases exhibited by subsets of participants. Analysis techniques are demonstrated and specific findings are discussed in terms of potential to affect future test results. In addition, cluster analysis is used to investigate an improved structure for the generic maintenance questionnaire used in a previous operational assessment. Suggestions are put forth for aggregating questions and creating a more efficient maintenance questionnaire.

DoD KEY TECHNOLOGY AREA: Computing and Software, Other (Test and Evaluation)

KEYWORDS: Test and Evaluation, Operational Testing, Survey Analysis, Computing and Software, Questionnaires, V-22 Osprey, VBA, OLE Automation

ANALYZING UNDERWATER HULL COATING SYSTEM WEAR FOR SURFACE COMBATANTS

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Current hull coating wear models are derived from dry film thickness (DFT) measurements and are only being used on aircraft carriers, less than four percent of the surface fleet. Dry film thickness is a complicated value because it currently encompasses the thickness of both anticorrosive and anti-fouling (AF) layers and is susceptible to paint swelling. An analysis of data taken from surface combatant hulls by hull roughness analyzer is performed to provide a more reliable means of measuring paint wear as a function of paint smoothing. This method provides important insight to ablation rates and initial exploration into a potentially useful model. In 1997, Wimmer performed a least squares regression to develop a model that predicts the total coating system wear on an aircraft carrier's hull using DFT measurements taken in drydock. In 1999, Ellis derived an estimate of the mean thickness of one coat of AF and a simple method for estimating the mean thickness of an aircraft carrier hull's total coating system following two operational cycles. Both models are used to determine their ability to predict hull coating wear for surface combatants and paint application distributions are analyzed to explain some of the variation experienced in their models.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Underwater Hull Coating System, Anti-fouling Paint, Hull Roughness Measurement

SCHEDULING AIRCREW TRAINING AT UNITED STATES NAVY FLEET READINESS SQUADRON HC-3 DURING REPLACEMENTS OF H-46D HELICOPTERS BY CH-60S

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The United States Navy is replacing the H-46D helicopter with the new CH-60S helicopter. Helicopter Combat Support Squadron Three (HC-3) is the U.S. Navy's Fleet Readiness Squadron, responsible for training the contingent of pilots and aircrewmen to fly this helicopter fleet; it is also responsible for managing their transition to the CH-60S. Each pilot and aircrewman represents a large investment in training and experience, and each is engaged in some stage of a Navy career that is governed by a host of guidelines for training, service experience, sea and shore duty rotations, and so forth. This thesis introduces an optimization model that takes as input the current state of Navy pilots and aircrewmen, the schedule of CH-60S introductions, restrictions on career duty tours and qualifying experience, limits on training resources, and other policy guidelines. The output is a schedule of duty tours, including training, retraining, shore, and sea duty tours, while recommending an optimal set of career paths to accommodate the transition over an 84-month period.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training

KEYWORDS: Training, Aviation, Optimization, Modeling, Logistics

SIMULATION OF CLASS A AND B TACAIR FLIGHT MISHAPS, ASSESMENT OF POTENTIAL HUMAN FACTORS INTERVENTION

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The increasing mechanical reliability of Naval Aviation (NA) aircraft has made human error (HE) the leading cause of Class A and B flight mishaps. To increase understanding of the underlying causes of HE, the Naval Safety Center in Norfolk, VA, developed the Human Factors Analysis and Classification System (HFACS). The HFACS taxonomy consists of 17 types of basic HE. This HFACS taxonomy has been used as a data analysis tool to classify 141 Class A and B Naval Tactical Aircraft (TACAIR) flight mishaps (FM) from fiscal year (FY) 90 to FY97. The study shows an important relationship between Adverse Mental State and 12 of the 17 HE types in the HFACS taxonomy. Significantly, when one of these 12 HE types is cited in an FM, greater than 70 percent of the time, Adverse Mental State is also cited as a co-causal factor in the mishap. Two other HE types have this 70 percent co-causal factor relationship with 3 of the 17 HE types. Adverse Mental State has an important relationship to the majority of the HE types in the HFACS taxonomy, compared with other HE types. For this reason, Adverse Mental State merits further investigation and should be considered in the development of HE prevention programs for Naval Aviators.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Human Systems Interface, Manpower, Personnel, and Training, Modeling and Simulation

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

SENSORY ADAPTATION EFFECTS FOLLOWING EXPOSURE TO A VIRTUAL ENVIRONMENT

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The Navy's operational manual 3710.7Q states that flight personnel exhibiting symptoms of simulator exposure must abstain from same-day flying duties, and those who have a history of simulator sickness must be removed from the flight schedule for at least 24 hours following simulator exposure. The cause of simulator sickness is currently unknown, but researchers hypothesize it results from a sensory-input mismatch between the visual and vestibular sensory organs. Previous simulator-sickness studies used questionnaires to measure sickness severity; however, this is a crude measure with inconsistent findings. The goal of this study was to determine quantitatively whether low-level sensory functions are disrupted in a virtual environment, and determine whether long-term simulator exposure causes sensory adaptation. In order to answer these questions, smooth pursuit parameters, perceptual distance estimation, horizontal eye movements, and relative comfort level were measured before and after immersion in four different display formats. This study failed to find any statistically significant changes in low-level vision functions. However, as with virtually every other study done on simulator sickness, this study did find statistically significant differences in comfort level (as measured with the Simulator Sickness Questionnaire) when using a head-mounted display and a 3-panel display as compared to a control condition.

DoD KEY TECHNOLOGY AREA: Human Systems Interface

KEYWORDS: Virtual Environment, Adaptation, Simulator Sickness, Human Performance, Eye Movements

A DECISION SUPPORT SYSTEM FOR AIRCREW SCHEDULING IN THE R.O.K. NAVY MARITIME PATROL SQUADRON

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The Republic of Korea (ROK) Navy operates maritime patrol aircraft for various missions. The maritime patrol squadron (MPS) assigns missions to each aircrew member via a daily flight schedule. Each crewmember must review the daily flight schedule and be prepared for his assigned flights. Actually creating the flight schedule presents a large scheduling problem. The squadron Scheduling Officer is responsible for generating, updating, and maintaining the flight schedules. In creating the flight schedules, he must adhere to specific regulations and guidelines that reflect operational readiness and flight safety requirements when assigning the 150 squadron members.

This thesis develops the Republic of Korea Maritime Patrol Squadron Decision Support System (ROK MPS DSS) that aids the Scheduling Officer by generating a flight schedule. The DSS includes a heuristic to generate the flight schedule. That heuristic is written in Microsoft Visual Basic. The DSS also includes a database developed in Microsoft Access and a graphical user interface for ease of use. The ROK MPS DSS generates a flight schedule for a user-designated time period, and also provides insight as to the impact of flight schedule changes. Thus, this DSS is an invaluable tool for the MPS since it provides a fast, reliable, and affordable solution to the flight scheduling problem.

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

KEYWORDS: Air Crew Scheduling, Decision Support System, Heuristic

TOMAHAWK STRIKE COORDINATOR PREDESIGNATION: OPTIMIZING FIRING PLATFORM AND WEAPON ALLOCATION

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Ships, submarines, and missiles are currently manually allocated for naval strike warfare tasking. Naval Surface Warfare Center Dahlgren Division has proposed to the Office of Naval Research to develop automated "predesignation" aids that automatically allocate the Tomahawk Land Attack Missile, at both the Tomahawk Strike Coordinator level, and at the individual firing platform level. A mixed integer program is introduced for Tomahawk Strike Coordinator predesignation, and is implemented in alternate forms and tested for a variety of scenarios.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Other (Conventional Weapons)

KEYWORDS: Tomahawk Land Attack Missile, Mixed Integer Program, Weapons Allocation

TACTICAL EXERCISE REVIEW AND EVALUATION SYSTEM

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This thesis designed, developed, and implemented an integrated data collection and display system for supporting After Action Reviews (AARs) for tactical exercise participants. Data is collected with small, inexpensive, and easy to use computers. The exercise is immediately replayed during the AAR by depicting unit locations, actions, interactions, and dependencies dynamically over a digital map on a computer display. The system is intended to increase the learning of the tactical exercise participants and ultimately improve their performance in combat. Conventional range instrumentation systems (RIS) are expensive. Tactical Exercise Review and Evaluation System (TERES) can meet the principal RIS requirements for a fraction of the cost and provide the flexibility to function at any location. The data collection subsystem utilizes commercial Global Positioning System (GPS) receivers and handheld personal computers (HPC) to collect data. The HPC is programmed to passively record positions and time along with specific mission-essential tasks inputted by an observer. The display subsystem utilizes digital military maps to provide an event step animation of the collected exercise data. NATO standard military symbols are used to represent unit identities and locations. With TERES, leaders and subordinates can more easily learn valuable lessons about synchronizing maneuver with direct and indirect fire. Questions about mission accomplishment, individual performance, and command and control can now be discussed with an objective tactical picture.

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

KEYWORDS: Training, After Action Reviews, Java, Loosely Coupled Components, Geographic Information Systems, Global Positioning System

ANALYSIS AND MODELING OF BACK INJURIES ABOARD U.S. NAVY VESSELS

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Work aboard U.S. Navy vessels is often physically demanding, and personnel working in such environments are frequently at risk of back injury. Between 1994 and 1998, the U.S. Navy reported 968 back injury mishaps aboard ships and submarines which resulted in 3,283 lost workdays, 5,753 days of restricted activity, and 611 days of hospitalization costing $4,758,000 in constant year 1998 dollars. The high frequency and enormous costs associated with back injury mishaps create an opportunity to increase personnel readiness and reduce operational costs through prevention. This study entailed an analysis of Afloat Special Case Mishaps for back injuries from 1 October 1993 to 30 September 1998 to develop a means of evaluating intervention effectiveness. Using descriptive statistics and categorical data analysis to measure injury arrival rates and identify back injury risk factors, a stochastic model of the back injury arrival process is developed as the foundation for event simulation. The simulation model of back injuries is then used to measure the expected outcome of interventions to reduce the number of injuries, days lost, days to restricted activity, days of hospitalization and total cost.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Injury Modeling)

KEYWORDS: Maritime Mishaps, Back Injury, Accident Analysis, Human Factors, Job Family, Event Modeling, Simulation, Accident Prediction

A PARAMETRIC COST MODEL FOR ESTIMATING ACQUISITION COSTS OF CONVENTIONAL U.S. NAVY SURFACE SHIPS

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When attempting to predict the acquisition costs of U.S. Navy surface ships, current models cannot produce a repeatable answer when the details of the acquisition program are not well defined. This thesis formulates a parametric model that predicts the average procurement cost of a conventional U.S. Navy surface ship based upon known (or assumed) physical and performance characteristics. The source data for the cost model is obtained from U.S. Weapons Systems Costs, a tabulation of annual procurement costs for major system programs, published by Data Search Associates. Standard regression techniques return cost estimating relationships able to predict average procurement cost from ship light displacement, ship overall length, ship propulsion shaft horsepower or number of propulsion engines. The formulated parametric cost model is approximate and appropriate only for rough order of magnitude studies, but can be used by the DoD cost community to produce justifiable estimates when other models do not have sufficient information to generate an answer.

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

KEYWORDS: Parametric, Cost Model, Surface Ship, Acquisition, Estimation

IMPROVING THE LAYOUT OF A WAREHOUSE AT THE COAST GUARD AIRCRAFT REPAIR AND SUPPLY CENTER

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This thesis presents a heuristic algorithm to evaluate alternative item and storage device locations in the Coast Guard's Aircraft Repair and Supply Center (ARSC) warehouse. The goal is to minimize the labor cost of item pickers by locating items in a way that reduces travel. The heuristic assigns items with the highest usage to the storage locations nearest the input/output point and evaluates alternative plans for relocating a limited number of storage devices by pairwise-interchange. The quality of the results were judged by comparing them to ARSC's current item locations and storage device layout. An iterative linear programming (LP) based algorithm that provides a lower bound on cost for comparison with heuristic's results was developed. Although implementing the iterative LP solution requires capital outlays beyond current budgets of the ARSC, the solution provides insight into layout and labor cost tradeoffs for long term planning. The results show that expected travel distances and labor costs can be reduced by 40.2% by reassigning items to locations within ARSC's current configuration of storage devices. By interchanging only 7 of 51 storage devices ARSC could gain an additional 5.6% improvement for a total 45.8% reduction. The iterative linear programming solution establishes a lower bound of 53.7% reduction over ARSC's current layout.

DoD KEY TECHNOLOGY AREA: Other (Warehousing)

KEYWORDS: Warehouse Layout, Order Batching, Aisle Travel Metric, Pairwise-Interchange, Assignment Problem, Excel, VBA

OPTIMALLY SCHEDULING EA-6B DEPOT MAINTENANCE

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Ranging from Operation Desert Storm to combat actions in the Balkans, EA-6B Prowler aircraft lie at the heart of nearly all tactical aircraft strikes. Providing a fleet capable of such combat actions in the next decade challenges the Prowler community to efficiently schedule EA-6B depot maintenance services. By 2009, EA-6B depots must conduct 80 wing center section replacements, 144 major aircraft modifications and standard depot level maintenance 154 times. There are several complex rules governing when each Prowler is eligible for each service; these rules are also flexible enough to allow more induction schedules than can be evaluated manually in a reasonable amount of time. Since each service removes aircraft from mission inventory for six to 12 months and performing multiple services together requires less time than performing services independently, services should be combined whenever possible. This thesis develops a mixed integer linear program, EA-6B Depot Maintenance Optimization Model (EDMOM), to help schedule EA-6B aircraft for depot maintenance services. EDMOM minimizes total time aircraft are removed from mission inventory; it produces an induction schedule for the EA-6B fleet through 2009 that adheres to all appropriate rules and conducts 378 services in only 216 inductions, requiring 2,446 total months. Without combining services, it would require 3,630 months, nearly a 50 percent increase.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Other (Optimization)

KEYWORDS: Mixed Integer Linear Programming, Aircraft Depot Maintenance, Optimization

AN ANALYSIS OF THE EFFECTS OF AVIATION CAREER CONTINUATION PAY (ACCP) ON NAVAL AVIATION RETENTION

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The U.S. Navy offers financial inducements to its pool of aviators as a retention tool. Navy officials are currently considering replacing the current system of bonus payments, known as Aviation Continuation Pay (ACP), with a revised system known as Aviation Career Continuation Pay (ACCP). ACCP ties annual lump sum payments to accession to seagoing career milestone billets, whereas ACP provides payment only for remaining on active duty. This thesis analyzes retention statistics from the Navy Officer Master File and other data sources to develop an Annualized Cost of Leaving (ACOL) model. The model parameter that designates a monetary equivalent for a predilection to remain in the service was extrapolated into elements of the ACCP program using career progression statistics to project the effect of switching to ACCP on retention. This extrapolation yielded an estimation of a 19.68 percent increase in retention through year of service (YOS) 11 to YOS 20, 29.72 percent from YOS 16 to 20, 13.9 percent from YOS 16 to 25, and 8.86 percent from YOS 21 to 25.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Aviation, Bonus, Retention, ACCP

SAFETY CLIMATE ASSESSMENT IN NAVAL RESERVE AVIATION MAINTENANCE OPERATIONS

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Naval Aviation's annual Class 'A' Flight Mishap rate is commonly used as a measure of safety effectiveness. Interventions implemented over the past four decades greatly reduced mishap occurrence by focusing on aircrew and supervisory error. Less attention has been paid to the role maintenance plays in Naval Aviation mishaps, though it is consistently responsible for approximately 16 percent of all Class 'A' Flight Mishaps. In 1998, a Maintenance Climate Assessment Survey (MCAS) was developed to evaluate safety concerns from the perspective of an aircraft maintainer. This thesis utilized the revised MCAS to assess its validity and utility as a diagnostic tool to access several aircraft communities within the Naval Reserve. It proved useful in aiding Commanders and Aviation Safety Officers (ASOs) in evaluating their maintenance operation's safety posture. The results of this study produced a finalized MCAS for fleet wide distribution. The findings will serve to encourage proactivity within aviation maintenance in the areas of safety awareness and risk management. This tool will also aid the monitoring of ongoing safety programs or implementation of new ones.

DoD KEY TECHNOLOGY AREA: Air Vehicles

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

NUMERICAL ANALYSIS OF FRATRICIDE IN UNITED STATES NAVAL SURFACE AND SUBMARINE FORCES IN THE SECOND WORLD WAR

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Friendly fire in naval warfare is a virtually unstudied phenomenon. In order to prepare future U.S. naval forces for the inevitable losses that will occur as a result of fratricide, we must look to the past to discover the role it has played in this century's wars at sea. This study examines the significance of friendly fire in U.S. naval surface and submarine operations during World War II and argues that the occurrence of self-inflicted casualties is a function primarily of the frequency and intensity of naval combat. Additionally, the causes of and factors contributing to naval fratricide are identified and discussed in detail using historical cases. The crucial result of this thesis is that even the most technologically advanced and highly trained force is subject to surprisingly high rates of friendly fire. Only when the vulnerability of every navy to fratricide is officially acknowledged can technology and doctrine be developed to reduce the risk of accidentally engaging one's own forces.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Fratricide, U.S. Naval Forces in World War II

FORECASTING CARRIER AIR-WING OPERATIONAL AVAILABILITY WITH EVENT STEP SIMULATION

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This thesis develops an event step simulation that models the Operational Availability (Ao) of carrier aircraft based on the supply and maintenance of Weapon Replaceable Assemblies (WRAs). It verifies that WRA allowances, developed by the Aviation Readiness Requirements Oriented to WRAs (ARROWs) model, achieve a target level of Ao given stated assumptions. It expands on ARROWs by characterizing not just the expected value of Ao but also its variability and probability distribution function. The simulation is expanded to include a variety of factors not considered by ARROWs. Examples of these factors include actual flight schedules, variable and prioritized requisitioning and repair, and cannibalization. The impact of these factors on the distribution of Ao is quantified. Simultaneous examination of all factors reveals that the full simulation predicts actual Ao approximately as well as ARROWs. In general, the full simulation overestimates Ao, and ARROWs underestimates Ao.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Aviation Retail Requirements Oriented to Weapon Replaceable Asseblies (ARROWs), Operational Availability (Ao), Readiness Based Sparing (RBS), Aviation Consolidated Allowance List (AVCAL)

A PROBABILISTIC MODEL COST ESTIMATION MODEL FOR UNEXPLODED ORDNANCE REMOVAL

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The Department of Defense's proposed Range Rule greatly increases the number of unexploded ordnance (UXO) contaminated sites that the services must decontaminate. Existing models for estimating the cost of UXO removal often require a high level of expertise and provide only a point estimate for the costs; they do not provide a probability distribution of the potential costs. This thesis presents a probabilistic cost estimation model created as an "add-in" for *Microsoft Excel*. A test database consisting of descriptive and cost information on the historic cleanup of nineteen contaminated areas is created. To demonstrate the model, the thesis filters the database to find eight historic records characteristically similar to a fictitious cleanup scenario, and uses information from these historic records to build probability distributions for six cost elements. The model applies Monte Carlo simulation to these probability distributions to build a probability distribution for the total cleanup cost. The resulting distribution shows that for this cleanup scenario the most likely per acre cost is $8,400, but there is a 75% chance that costs fall between $8,500 and $26,000. Results for a scenario composed of three cleanups predicts a most likely total cost of $1.7 million with a 50% probability of costs falling between $1.7 million and $2.2 million.

DoD KEY TECHNOLOGY AREAS: Environmental Quality, Modeling and Simulation, Other (Unexploded Ordnance)

KEYWORDS: Cost Estimation, Environmental Quality, Unexploded Ordnance, Risk and Uncertainty Analysis

OPTIMIZING NAVY WHOLESALE INVENTORY POSITIONING

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Naval Inventory Control Point (NAVICP) manages more than 186,000 Depot Level Repairable (DLR) line items in its wholesale inventory. It positions this materiel within a distribution network of 23 Defense Logistics Agency Depots and the privately owned Premium Transportation Facility (PTF). NAVICP plans to reduce materiel distribution time and optimize use of the distribution network to comply with mandated reductions in requisition response time. This thesis develops an Integer Linear Program (ILP) that positions one or more line items to achieve minimum distribution time subject to cost and other constraints. It derives a 57 line item test set composed of DLRs most likely to benefit from re-positioning: items with recent and projected demand and low weight. It also finds a simplified six-mode transportation scheme and an aggregated customer scheme that renders an ILP that is simple to use and captures the relationships that exist within the distribution network. Extensive analysis of the distribution network using the ILP indicates the Navy can cut response time and distribution cost by better strategic positioning of wholesale inventory within the existing network. These savings can be achieved by increasing use of PTF and considering use of storage depots not co-located with Navy activities.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Inventory, Positioning, Depot Level Repairables, Logistics Response Time, Materiel, Distribution

A DECISION SUPPORT SYSTEM FOR SEA-BASED SUSTAINMENT OPERATIONS

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The Marine Corps plans to fight battles in the 21st century using the littoral battlespace to maneuver forces from a sea-base to the operational objective. Combat forces ashore will be sustained directly from a sea-base to allow combat elements to maneuver freely without having to defend a rear area. In this type of environment, planners must be able to convert current data, intelligence, and status reports of units ashore into useful planning information. A sea-based sustainment posture makes transportation assets in the ship-to-objective delivery network critical for sustainment.

This thesis focuses on sustainment and distribution in a sea-based environment. The Sea-Based Logistics Decision Support System (SBLDSS) is developed to assist sustainment planners in this environment to predict inventory levels of forces ashore and assist in managing transportation assets. First, typical forces are modeled to reflect both their composition and activities ashore. Resupply needs are determined based on the commander's concept of operations and logistics planning factors developed for each force. Transportation assets, used to sustain the forces, are modeled. Demand is then placed on these transporters by both logistical and operational missions. Finally, a utilization schedule is constructed to determine if a feasible distribution plan exists.

DoD KEY TECHNOLOGY AREA: Other (Logistics)

KEYWORDS: Operational Maneuver From The Sea (OMFTS), Ship-to-Objective Maneuver (STOM), Sea-Based Logistics (SBL), Sustainment, Distribution, Decision Support System

A COMPARISON OF SUSTAINMENT TACTICS FOR A FUTURE NAVAL FORCE

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Since 1995, the charter of the CNO's Strategic Studies Group has been to generate revolutionary concepts in Naval Warfare. In that effort, it has envisioned a highly capable Forward Deployed Force (FDF) suited for operating in a dispersed architecture – separated by distances of up to 100 nautical miles. The heart of the FDF is eight cruiser-destroyer sized Combatants. It also includes two Expeditionary Ships, a Logistics Ship, and an Aircraft Carrier, which serves mainly as a support platform for the FDF's manned and unmanned aircraft. This represents a significant departure from modern Carrier Battlegroups. It is debatable whether current sustainment tactics will prove suitable in such an operational environment. In fact, the SSG has developed its own delivery tactic, "Distributed Logistics," using small, fast delivery platforms to overcome anticipated shortcomings of the current delivery by "Delivery Boy" and "Service Station."

This thesis compares two variants of Distributed Logistics against three variants of the traditional Delivery Boy and Service Station tactics in terms of delivery capability, survivability, and cost. Hybrid delivery tactics are also introduced combining the multiple logistics ships with the small delivery platforms of Distributed Logistics. The resulting analyses show that the FDF is sustainable using variants of the traditional Delivery Boy tactic. However, if the threat of loss is significant, hybrid delivery tactics provide similar delivery capability and significantly greater survivability for less cost.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation, Other (Combat Logistics Support)

KEYWORDS: Sustainment, Replenishment Tactics, Modeling

OPERATIONAL MANEUVER FROM THE SEA
LOGISTICS TRAINING AID
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Changes in the global situation resulting from the demise of the Soviet Union have lead to major restructuring in United States' military. As a result the Navy and Marine Corps have reevaluated amphibious concepts, resulting in Operational Maneuver From the Sea (OMFTS), and Sea Based Logistics (SBL). OMFTS supported by SBL rely on a "sea-base" to act as the staging area for the dissemination of supplies to the amphibious units ashore. This close integration of Navy and Marine Corps logistics requires Naval Officers and Marine Corps Officers be aware of each other's requirements.

Current training aids do not model OMFTS and SBL. To facilitate training, a modular computer-based wargame called NAVLOGS has been developed with the logistics concerns of OMFTS and SBL in mind. The core classes of NAVLOGS include the Scenario Builder, the Coastline Model, and a Map Scale Generator. These core classes enable the user to create scenarios for NAVLOGS with little or no programming skill thus taking scenario design from the programmers and giving it to the end user.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Operational Maneuver From the Sea, Naval Expeditionary Logistics, NAVLOGS, Sea-Based Logistics, Ship to Objective Maneuver

SENSITIVITY OF SUBMARINE HYPERSPECTRAL CONTRAST
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Second Reader: Capt Scott Tyo, USAF, Department of Electrical and Computer Engineering

This thesis investigates the operational implications of a Hyperspectral Imager (HIS) used to find submerged objects in natural, ocean water. The model used for this thesis consists of Hydrolight© version 3.0 developed for the Office of Naval Research. This code uses solutions to the radiative transfer equations to describe underwater light field properties. Target and sea surface optical properties are simulated by GenTarget and GenScene, both developed by Photon Research Associates, Inc. Given environmental variable values and target and sensor geometries, these codes develop an image cube as it would be perceived at an HIS's sensor head.

The models are used to determine the maximum sweep width given a fixed probability of false alarm. By parametric analysis, complex relationships and interactions can be replaced by suitable linear approximations to reduce the complexity of calculations and the dimensionality of the input set required to describe detectability.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

KEYWORDS: Hyperspectral Imaging, ASW, Remote Sensing, Optical Oceanography

NAVAL LOGISTICS SIMULATOR

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This thesis provides initial development of an interactive simulation for training Operational Logistics students in the management of Naval Operational Logistics. The model is designed with a modular architecture, enabling the flexibility to upgrade or modify selected components without altering the rest of the simulation. The simulation is implemented in the Java programming language, allowing the model to run on all major operating systems. The major components of the model include a discrete event simulation, a Graphical User Interface (GUI), and controller classes that connect the two. These controller classes pass user commands to the non-visual simulation for execution and information from the simulation to the GUI for display. Data required by the non-visual simulation is inputted from a separate database and configuration files. This feature allows the simulation to run different scenarios with distinct maps and graphics with no modification to the compiled computer code. The simulation and data structure developed in this thesis provide a solid foundation for further expansion into a fully featured interactive naval logistics training simulation.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Java, Logistics, Modeling and Simulation, NAVLOGS

DISTRIBUTION OF FIRING DIRECTIONS IN A COORDINATED SURFACE-TO-SURFACE MISSILE ENGAGEMENT

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The Norwegian Air Force and the Norwegian Navy both use the Norwegian developed Penguin surface-to-surface missile (SSM) but they use different tactics for launching it. The Navy recommends many attack directions, whereas the Air Force has the missiles approach the target area along a single axis.

This thesis investigates the effectiveness of different attack geometries using a discrete event simulation model that captures objects in motion, the detection of targets, the distribution of information, and the engagement procedures. The model includes ships, sensors, a data-link, missiles, missile batteries, air-target trackers, guns and the anti-air-warfare organization. Based on data from open sources, the simulation model of this thesis demonstrates that having all missiles approach the target area along the same bearing is the preferred SSM launch tactic under a variety of circumstances.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control, and Communications, Computing and Software, Conventional Weapons, Sensors, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Surface Ships, Surface-to-Air Missiles, Surface-to-Surface Missiles, Guns, Radar, Air-target Trackers, Air-Defense Organization