MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

OPTIMAL LONG-TERM AIRCRAFT CARRIER DEPLOYMENT PLANNING WITH SYNCHRONOUS DEPOT LEVEL MAINTENANCE SCHEDULING

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Forward deployment of Navy aircraft carrier battle groups is a primary means for the United States to achieve overseas interests. The Navy maintains the forward presence of aircraft carriers in three major Areas of Responsibility (AORs): the Mediterranean Sea, the Persian Gulf, and the Western Pacific. Considering the cost of carrier operations and the desire to maximize coverage of the AORs, planning deployments for the carriers not only significantly affects the achievement of U.S. defense strategy, but also impacts the Navy financially. Previous studies have maximized the deployment of aircraft carriers to the AORs while strictly adhering to the fixed, long-range maintenance schedules published by the Planning and Engineering for Repairs and Alterations Activity for Aircraft Carriers (PERA CV). This thesis optimizes aircraft carrier deployment planning while shifting the pre-scheduled maintenance availabilities well within limits allowed by the Chief of Naval Operations (CNO). This synchronous planning of deployments and major maintenance yields at least 15% more planned coverage in the AORs with the existing carrier fleet. Such an increase had heretofore been thought to require three additional aircraft carriers.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Undersurface Vehicles – Ships and Watercraft, Modeling and Simulation, Other (Optimization)

KEYWORDS: Aircraft Carriers, Deployment Planning, Depot Level Maintenance, Crisis Response Times, Coverage of Areas of Responsibility, Optimization

PARTIAL-ENUMERATION FOR PLANAR NETWORK INTERDICTION PROBLEMS

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In the network interdiction problem, an interdictor destroys a set of arcs in a capacitated network through which an adversary will maximize flow. The interdictor's primary objective is to use his limited resources to minimize that maximum flow, but other objectives may be important. Therefore, we describe algorithms for enumerating near-optimal interdiction sets in planar networks so that these sets may be evaluated with respect to secondary criteria, e.g., safety of attacking forces, collateral damage, etc. The algorithms are based on enumerating near-shortest paths or cycles in the dual of a planar network; they find a single optimal interdiction set in pseudo-polynomial time. One algorithm was implemented applicable to *s*-*t* planar networks (*s* and *t* must lie on the perimeter of the network) and solve problems with up to 512 nodes and 791 arcs. An example of computational results on that largest network is that the algorithm enumerates all 959 solutions that are

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within 10% of optimal in 3.46 seconds on a 133 mHz Pentium PC. It was also proposed, but not implemented, at a somewhat less efficient extension of this algorithm to solve problems on general planar networks.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Network Interdiction, Dijkstra's Algorithm

MINIMIZING ARMY CADET TEMPORARY DUTY

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Every newly-commissioned Army officer from a Reserve Officer Training Corps (ROTC) commissioning source joins one of 19 different basic branches (e.g., infantry, armor) and undergoes initial training to develop fundamental skills at an Officer Basic Course (OBC). Each basic branch has a separate training program and offers multiple OBC classes every year. The Army grants commissions to approximately 3,000 ROTC cadets annually and, under the current system, manually schedules each cadet to attend an OBC class. In addition, the Army schedules approximately 850 of these cadets to fill one of two temporary duty (TDY) assignments en route to their OBC class. This thesis develops a mixed integer linear program called Minimizing Cadet Temporary Duty (MCTDY) to reduce the time needed to schedule cadets and reduce the TDY costs as well as pay and allowances incurred by all second lieutenants prior to their OBC class. For 2,828 cadets receiving commissions in 1998, MCTDY produces face-valid, cost-effective results. Direct comparisons between MCTDY and manual schedules are not made but experiments with MCTDY indicate a difference in TDY costs of up to $15 million is possible.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Personnel Scheduling, Army ROTC, Officer Basic Course, Mixed Integer Linear Programming

SURFACE SHIP SENSOR EMPLOYMENT AGAINST DIESEL SUBMARINES

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This thesis provides tactical guidance for employment of surface ship sensors against torpedo-armed diesel submarines during littoral operations. Advantageous utilization of antisubmarine sensor systems in the littoral environment incorporates a blend of competent tactical experience and innovative thought processes and reflects environmental conditions, threat status, and mission priorities. Through extensive use of a modeling and simulation program, this thesis determines the preferred sensor employment configurations based on surface ship and submarine detection and counter-detection ranges and vulnerabilities to torpedo attack. Preference is based on a measure of effectiveness that minimizes the risk faced

by surface ships from a diesel submarine threat, and provides tactical recommendations that are readily implementable as sensor employment policies.

DoD KEY TECHNOLOGY AREA: Electronic Warfare, Sensors, Surface/Under Surface Vehicles – Ships and Watercraft, Modeling and Simulation

KEYWORDS: Antisubmarine Tactics, Simulation, Sensor Employment, Antisubmarine Warfare

FIRST TERM ATTRITION OF FUNDAMENTAL APPLIED SKILLS TRAINING (FAST) STUDENTS

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Fundamental Applied Skills Training (FAST) provides assistance to recruits with literacy skills deficiencies that could prevent them from successfully completing the recruit training cycle at Recruit Training Command, Great Lakes, Illinois. Short-term success of the program is known, but the long-term effects of this training are not known. In response to a Navy Training Requirements Review action item, this thesis examined the first term attrition of FAST students from Fiscal years 1993 and 1994 at yearly intervals. Analysis determined that FAST students have significantly lower attrition rate throughout the first term and a significantly higher reenlistment rate for a second term than sailors of similar abilities. Attrition of FAST students was similar to that of sailors of the upper mental group during the first term. The thesis includes a general overview of FAST research and a concise history of FAST development.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: FAST, Attrition, Naval Training, Navy Personnel, Skills

MINIMIZING DRUG RELATED ATTRITION COSTS FOR INCOMING NAVAL RECRUITS

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This thesis investigates alternative strategies for enforcing the Navy's zero-tolerance drug use policy among Navy recruits. Current policy relies mainly on the gas chromatography/mass spectrometry (GC/MS) urinalysis for recruits when they arrive at boot camp. GC/MS, a laboratory test, takes at least three days for confirmation. The cost of separating recruits who fail urinalysis or admit to drug use at boot camp is $2.7 million per year.

Key ideas investigated in the thesis are the administration of drug tests at Military Entrance Processing Stations (MEPS) on the day of shipping to boot camp, and the use of a new "non-instrumented" drug test (NIDT). The NIDT, though not as accurate as GC/MS, requires no laboratory equipment or expertise to administer and furnishes results immediately.

This thesis designs and recommends a new policy which includes NIDT testing for marijuana at the MEPS in addition to GC/MS at RTC. Through the use of detailed statistical, cost and sensitivity analyses, the thesis concludes that the Navy

can save well over a $1 million per year by instituting this policy. These results have been reported to RADM Kevin Green, Commander of NTC, Great Lakes, who has announced his intention to adopt the new policy.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Recruit, Drug Testing, Attrition, Optimization, Policy, RTC Separation Costs

OPTIMIZING SELECTION OF TOMAHAWK CRUISE MISSILES

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The Tomahawk Land Attack Cruise Missile (TLAM), launched from surface ships and submarines, has become the weapon of choice for the United States in many situations. In an era of high-precision, fast-delivery weapons, the method currently used for assigning TLAM engagements is out of step with the development of the weapons themselves. Missile assignment today is manual, with the potential consequences of inefficient missile-to-mission matching and unnecessary delay.

This thesis develops a new optimizing approach to missile-to-mission matching, using integer programming. In a matter of seconds for a single ship or a matter of minutes for a battle group, the optimization model determines which missile to select for each tasking order and provides back-up assignments if requested. The objective of the model is to ensure the correct weapon is applied against each target while maximizing the potential of the firing unit(s) to perform future taskings.

The new missile-to-mission matching model is better than current methods and performs robustly in extensive sensitivity analyses. The optimization model is currently being considered for shipboard implementation by the Naval Surface Warfare Center. At the very least, the model can be used to independently assess the performance of any new missile-to-mission matching decision support considered by the Navy.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Conventional Weapons

KEYWORDS: Tomahawk Land Attack Cruise Missiles (TLAM), Vertical Launch System (VLS), Missile Selection, Missile-to-Mission Matching (M3)

A FORCED ENTRY PLANNING MODULE FOR AMPHIBIOUS AIR ASSAULTS FOR THE JOINT WARFARE ANALYSIS EXPERIMENTAL PROTOTYPE

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The most difficult challenge in modeling and simulating modern warfare is the attempt to address every possible scenario, operating plan, and tactic. One such model is the Joint Warfare Analysis Experimental Prototype (JWAEP) being developed at the Naval Postgraduate School. A scenario in which JWAEP needs further development is littoral warfare, which for the Marine Corps represents amphibious assault operations. An aspect of this type of warfare is referred to as “forced entry” when friendly ports are not available in the region of interest. Forced entry occurs by air, sea, or a combination of air and sea. Although these missions are very complex, mission planning is similar for each mode of transport. This thesis introduces the Forced Entry Planning Module (FEPM), a tactical decision planning aid, and offers a test of the conceptual amphibious air assault portion of FEPM using the most current United States Marine Corps amphibious air assault doctrine.

The concept was tested by constructing a stand-alone model, using deterministic combat attrition, to evaluate three potential methods for choosing a route to an amphibious air assault objective under uncertainty. The results indicated that each of the proposed methods predicted mission outcome under uncertainty with varying degrees of success. This limited testing has validated the concept of FEPM and the proposed methods. However, further refinement and testing is required before a final determination of which method is "best" for evaluating routes for forced entry missions is made.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Forced Entry Planning Mode (FEPM), Joint Warfare Analysis Experimental Prototype (JWAEP), Wargaming, Simulation, Uncertainty, Stochastic Modeling

A MONTHLY SORTIE SCHEDULING MODEL FOR IMPROVED EA-6B PROWLER COMBAT READINESS

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EA-6B Prowler crews conduct a variety of missions and are required to fly and train with sufficient regularity to maintain combat proficiency. These crews maintain this proficiency by completing regularly scheduled training qualifications. Squadrons determine their readiness level based on the percentage completion of these qualifications. Squadrons currently use an *ad hoc* method for scheduling training. This thesis develops a mixed integer program to plan monthly sorties, as a decision aid for squadron operations officers. The goal is to maximize squadron combat readiness by minimizing the number of aviators not fully combat-ready, subject to the number of flights available. The model is programmed in the GAMS language and uses a spreadsheet interface for both input and output. It is typically solved in 10 minutes on a Pentium 120 MHz PC with the OSL solver. The output is a matrix of pilots to flight assignments and aircrew to flight and seat assignments. This approach immediately yields a 10% improvement in average monthly readiness as compared to the *ad hoc* method and should be implemented as a methodology for scheduling monthly sorties.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: COMNAVAIRPACINST 3500.67C, EA-6B Prowler, Readiness, Scheduling, Training

CLASSIFICATION TREE ANALYSIS OF HELICOPTER INTEGRATED DIAGNOSTICS SYSTEM (HIDS) MECHANICAL VIBRATION FAULT INDICATORS IN SH-60 (SERIES) HELICOPTER TRANSMISSION SYSTEMS

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Helicopter Integrated Diagnostic Systems (HIDS) performs real time mechanical vibration fault diagnosis in flight. The United States Navy has recently contracted for 12 open systems for its Seahawk and Sea Stallion aircraft. The system provides warning to flight crews when a number of HIDS parameters are exceeded. These parameters are indicators of failing transmission components.

This thesis makes use of a non-parametric technique called tree-structured classification to analyze HIDS vibration indicators. Three Seahawk helicopter failed transmission cases are considered, including analysis of an operational aircraft

transmission bearing fault that was detected by HIDS. The analysis is focused on differentiating a faulted component from a normally functioning one based on the indicator's numerical value. The prevention of false alarms is considered in this analysis. The research in this thesis was requested by NAVAIR 4.4.2. The vehicle for analysis is the embedded Classification Tree method in S Plus 4.0 (Mathsoft Inc., 1997) a PC based statistical software product.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: CART, Classification and Regression Tree, Helicopter Integrated Diagnostic System, Helicopter Diagnostics, Helicopter Maintenance, Helicopter Vibration, HIDS, HUMS, Mechanical Vibration Diagnostics, Tree-structured Classification, VATS

AN ANALYSIS OF AVIATION TEST SCORES TO CHARACTERIZE STUDENT NAVAL AVIATOR DISQUALIFICATION

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The U.S. Navy uses the Aviation Selection Test Battery (ASTB) to identify those Student Naval Aviator (SNA) applicants most likely to succeed in flight training. Using classification and regression trees, this thesis concludes that individual answers to an ASTB subtest, the Biographical Inventory, are not good predictors of SNA primary flight grades. It also concludes that those SNA who score less than a six on the Pilot Biographical Inventory have a significantly higher disqualification rate in primary flight training than those SNA who score a six or higher. Those SNA who repeat the taking of the ASTB are more likely to disqualify from primary flight training than those SNA who pass it on the first attempt. Incidentally, significant differences exist in SNA performance and disqualification rates in Aviation Preflight Indoctrination among different racial groups. However, neither race nor gender is a significant factor in primary flight-training disqualification. Recommendations are provided to reduce the number of SNA entering the flight-training pipeline, if necessary, while significantly reducing the disqualification rate. Additionally, a method is given to identify those SNA most at risk of disqualifying from primary flight training.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Attributes, Attrition, Cross-Validation, Disqualification, Partition, Tree

OPTIMAL USE OF GERMAN ARMY MAINTENANCE RESOURCES

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The German Army's maintenance branch, having lost 25 percent of its soldiers since the end of the Cold War, has insufficient military personnel within maintenance units to maintain all combat units' equipment. The Army, therefore, purchases civilian man-hours (mhrs) to satisfy some required maintenance. This thesis develops a mixed integer linear program, named ADOPT (administrative order optimizer), to optimally assign combat units' equipment to maintenance units and to predispose a budget to purchase civilian mhrs. ADOPT also determines beneficial cross-training of soldiers from one maintenance type to another. Since it is not always possible to maintain all combat units' equipment, ADOPT minimizes the gap, prioritized by equipment types, between needed maintenance mhrs and available military and civilian maintenance

mhrs. ADOPT provides a tool to determine and evaluate options and principles that impact the readiness of a German Army Division's materiel. ADOPT validates its effectiveness with data of Military District VIII/ 14th Mechanized Infantry Division. Results indicate a potential budget saving of one-third when cross training of maintenance soldiers from one maintenance type to another is allowed. ADOPT also shows that the regional principle (assigning common combat units' equipment to the nearest maintenance units) is inefficient.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Assignment, Maintenance, Equipment, Mixed Linear Integer Programming

EVALUATION OF THE IMPACT OF MULTISPECTRAL IMAGE FUSION ON HUMAN PERFORMANCE IN GLOBAL SCENE PROCESSING

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An observer extracts local and global information from a natural scene to form a visual perception. Neisser (1967) and Treisman (1985) demonstrated that a natural scene contains different types of features, i.e., color, edges, luminance, and orientation to aid visual search. Infrared and visible sensors present nighttime images to an observer to aid target detection. These sensors present the observer an adequate representation of a nighttime scene, but sometimes fail to provide quality features for accurate visual perception. The purpose of this thesis is to investigate whether color features (combining an infrared and visible sensor image) improve visual scene comprehension compared to single-band grayscale features during a signal detection task. Twenty-three scenes were briefly presented in four different sensor formats (infrared, visible, fused monochrome, and fused color) to measure subjects' global visual ability to detect whether a natural scene was right side up or upside down. Subjects are significantly more accurate at detecting scene orientation for an infrared and fused color scene compared to a fused monochrome and visible scene. Both the infrared and fused color sensor formats provide enough essential features to allow an observer to perceptually organize a complex nighttime scene.

DoD KEY TECHNOLOGY AREA: Sensors

KEY WORDS: Sensor Fusion, Visual Perception, Preattentive Processing, Infrared

A JOINT SERVICE OPTIMIZATION OF THE PHASED THREAT DISTRIBUTION

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The decreasing defense budget forces the Department of Defense (DoD) to continually find areas in which to reduce military spending. Traditionally, each service has requested munitions considering itself in isolation. This inevitably leads to excessive munitions acquisition for the DoD as a whole. The Under Secretary of Defense for Acquisition and Technology developed the Capabilities-Based Munitions Requirement (CBMR) process to ensure that the DoD address the munitions acquisition issue from a joint perspective and thus reduce excess.

The CBMR process requires each warfighting CINC to produce a phased threat distribution (PTD). The PTD specifies which friendly platform will be assigned to each enemy platform for a given scenario. This provides the services with estimates of the threats they must be prepared to overcome and the munitions they need. The purpose of this thesis is to help

develop the PTD in such a way that the threats are assigned appropriately with limited overlap among the services.

To achieve this purpose, the thesis develops a goal programming model that attempts to find an optimal allocation based on three objectives: minimize friendly casualties, maximize enemy casualties, and maximize adherence to the guidance delineating a proper division of labor among the services.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Phased Threat Distribution, Munition, Capabilities-Based Munition Requirement Process