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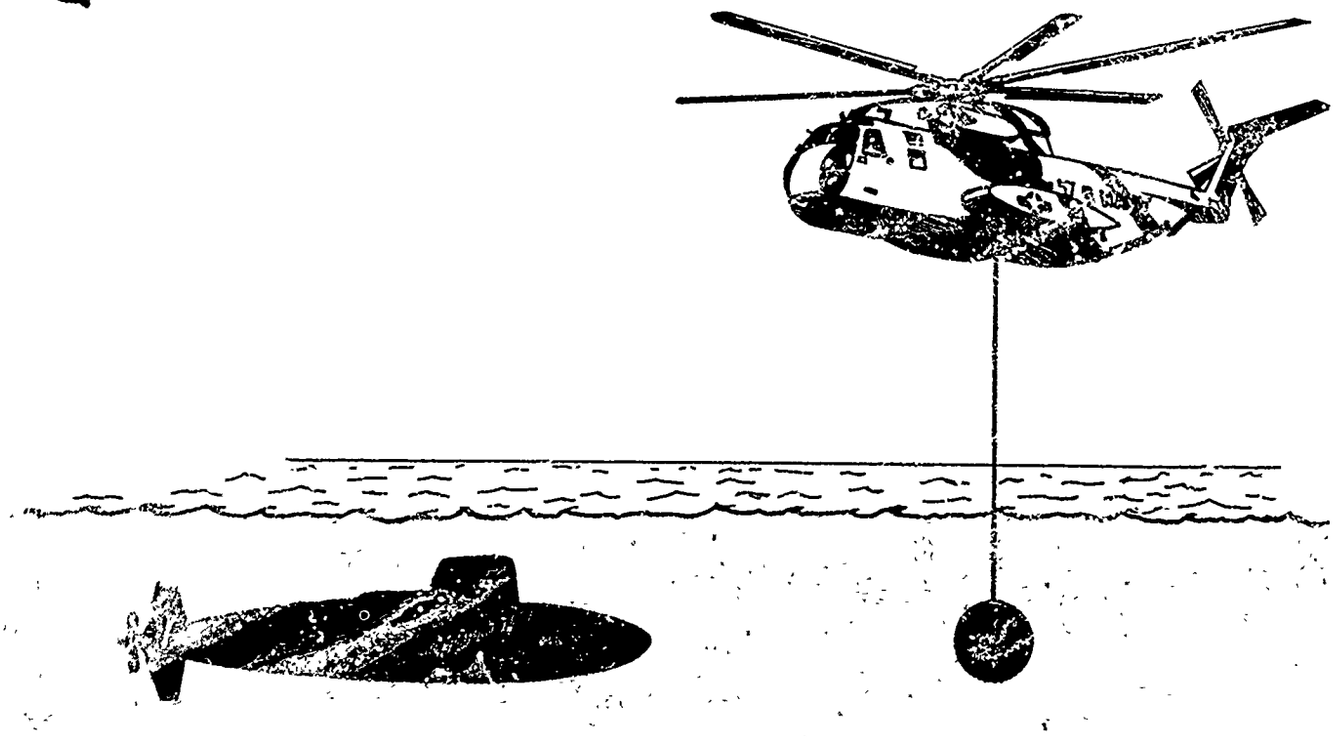
A STUDY OF MEASURES OF EFFECTIVENESS USED IN NAVAL ANALYSIS STUDIES



ultrasystems

JLTRASYSTEMS, INC.
500 NEWPORT CENTER DRIVE
NEWPORT BEACH, CALIFORNIA

ONR CONTRACT:
N00014-71-C-0247
FINAL REPORT
31 OCTOBER 1972

AUG 16 1973

VOLUME 4
MOE REVIEWS

A STUDY OF MEASURES OF EFFECTIVENESS USED IN NAVAL ANALYSIS STUDIES

Volume 4
MOE Reviews

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ONR Contract: N00014-71-C-0247
Final Report
31 October 1972

Prepared for

Office of Naval Research
Naval Analysis Programs

Prepared by

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500 Newport Center Drive
Newport Beach, California 92660

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(1)

AIRBORNE ASW

MOE REVIEW NO. (1)-1

A. STUDY DESCRIPTION

1) Originating Activity: Operations Research Incorporated, Silver Spring, Maryland
2) Report Title: Influence of Human Factors on Air ASW Sonobuoy Systems Effectiveness.
3) Authors: O. L. Stickel, H. N. Siebenberg, D. J. Sanders and M. J. Ginsburg
4) Report Number: TR 464 (AD-389 156)
5) Date: 1 November 1967
6) Classification: Secret
7) Contract: N60921-67-C-0229 (ASW Systems Project Office)
8) Abstract: This study considers the influence of human factors on optimum sonobuoy configuration performance. A methodology and model are developed for studying the effects of the aircrew in terms of data handling dalays and of signal classification. This model is then used for a sensitivity analysis of the effect of these human factors on sonobuoy system performance.
9) Descriptors: Aircraft, antisubmarine warfare, classification, MAD, sonobuoy, submarine

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Airborne ASW
3) Applicable Situation: Evaluation of MAD sensor performance
   3.1) Criterion For Success: Detection of submarine
   3.2) MOE Selected:
      (a) Probability of obtaining a MAD contact
         Rationale For Selection: Given an initial datum, the ultimate confirmation of submarine existence is

a MAD contact. The success in accomplishing this event depends upon operator performance of the ASW crew in terms of data handling, delay times and classification accuracy.

MOE REVIEW NO. (1)-2

A. STUDY DESCRIPTION

1) Originating Activity: Operations Research Incorporated, Silver Spring, Maryland
2) Report Title: Air ASW Sonobuoy Effectiveness in Prosecution Operations
3) Authors: O. Stickel, D. J. Sanders and H. N. Siebenberg
4) Report Number: TR 510 (AD-393 238)
5) Date: 31 July 1968
6) Classification: Secret
7) Contract: N60921-67-C-0229 (ASW Systems Project Office, Naval Material Command)
8) Abstract: This report presents a comparison of current and projected sonobuoy systems to be employed in air ASW prosecution operations. The effects of the data-handling and classification process in ASW aircraft are used to examine the relative effectiveness of active, explosive echo ranging, (EER), and directional passive sonobuoys in pre-ANEW aircraft.
9) Descriptors: Aircraft, antisubmarine warfare, classification, cost, Difar, Lofar, MAD, Monte Carlo method, sonobuoy, submarine

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Airborne ASW
3) Applicable Situations:
   3.1) Type: Evaluation of MAD sensor performance
      3.1.1) Criterion For Success: Detection of submarine
      3.1.2) MOE's Selected:
         (a) Probability of the aircraft obtaining a MAD detection given an initial datum

Rationale For Selection: This system effectiveness measure reflects both the redetection (range) capability and the quality of information supplied to the aircraft in reducing the initial time late and datum error.

(b) Cost per sortie, which is defined as the sum of the investment cost (aircraft and avionics), aircraft cost, and cost of expendables

3.2) Type: Evaluation of operator classification performance

3.2.1) Criterion For Success: Accurate classification of false targets.

3.2.2) MOE Selected:

(a) Rate of occurrence of incorrectly classified false contacts

Rationale For Selection: This measure represents the combined effects of the probability of correctly classifying a nonsubmarine as a submarine and the rate of occurrence of false contacts.

MOE REVIEW NO. (1)-3

A. STUDY DESCRIPTION

1) Originating Activity: Operations Research Incorporated, Silver Spring, Maryland
2) Report Title: Analytical Models of ASW Sonobuoy Effectiveness; III. Kill
3) Authors: D. Melnick and H. N. Siebenberg
4) Report Number: TM 119-65 (AD-377 037)
5) Date: 1 July 1965
6) Classification: Confidential
7) Contract: NOw 64-0489-C (Bureau of Naval Weapons)
8) Abstract: Analytical models are developed to describe the elements of the interface, during transition, track and attack, between ASW localization and kill operations. The primary emphasis in the report is to provide an analytical basis to compare existing and proposed hardware and tactics for VP and VS aircraft.
9) Descriptors: Aircraft, antisubmarine warfare, detection probability, Julie, localization probability, MAD, sonobuoy, submarine, torpedo

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Airborne ASW
3) Applicable Situations:
   3.1) Type: Evaluation of the performance of Julie sonobuoys
      3.1.1) Criterion For Success: Localization of target
      3.1.2) MOE's Selected:
         (a) Probability of localizing the target
         (b) Probability of obtaining a fix from an omnidirectional Julie contact

3.2) Type: Evaluation of submarine tracking capability by means of sonobuoys

3.2.1) Criterion For Success: Track of target to obtain accurate fixes for constant surveillance or, if required, a successful weapon drop

3.2.2) MOE's Selected:

(a) Probability that the target can be tracked for a given length of time

(b) Probability of maintaining contact for a given length of time with a specified number of buoy drops

3.3) Type: Evaluation of MAD tactics

3.3.1) Criterion For Success: Detection of submarine

3.3.2) MOE's Selected:

(a) Probability of submarine escape

(b) Probability of missing the submarine per aircraft cycle

(c) Probability of successfully performing MAD hunting operations

(d) Probability of detection on a single cycle

3.4) Type: Evaluation of the outcome of an airborne torpedo drop in the vicinity of a target datum

3.4.1) Criterion For Success: Acquisition of target

3.4.2) MOE Selected:

(a) Probability of target acquisition by the torpedo

MOE REVIEW NO. (1)-4

A. STUDY DESCRIPTION

1) Originating Activity: Anti-Submarine Warfare Force (Pacific), San Francisco, California
2) Report Title: ASW Fixed Wing Aircraft Evaluation Project
3) Report Number: COMASWFORPAC memo Ser. 7/00110 to CNO (AD-506 364)
4) Date: April 1969
5) Classification: Secret (NOFORN)
6) Abstract: This report documents and analyzes the series of events which constitute the VP/SOSUS tracking of a nuclear out-of-area contact. Data provided by the reconstruction is reported and analyzed in depth to produce measurements of a variety of effectiveness parameters.
7) Descriptors: Aircraft, antisubmarine warfare, ASCAC, classification, contact investigation, Jezebel, Lofar, SOSUS, submarine, surveillance, tracking

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Airborne ASW
3) Applicable Situations:
   3.1) Type: Evaluation of aircraft detection capability of submarines
      3.1.1) Criterion For Success: Detection of submarine
      3.1.2) MOE's Selected:
         (a) Percentage of sorties gaining contact
         (b) Fraction of opportunities detected for a specified range
   3.2) Type: Evaluation of the performance of a buoy field
      3.2.1) Criterion For Success: Detection of submarine
      3.2.2) MOE's Selected:
         (a) Fraction of opportunities in [illegible] detection is made

(b) Frequency of multiple simultaneous buoy contacts
Rationale For Selection: Since simultaneous contact on two or more buoys is ordinarily required to reduce the target uncertainty area, this measure provides a useful assessment of buoy field capability.

3.3) Type: Evaluation of the Lofar classification performance of an airborne Jezebel operator or ASCAC analyst

3.3.1) Criterion For Success: Accurate classification of Lofar gram signatures

3.3.2) MOE's Selected:

(a) Conditional probability that the airborne operator/ASCAC analyst correctly classifies a submarine signature

(b) Fraction of valid submarine signatures present on the Lofar gram that are recognized by the analyst (airborne/ASCAC)

(c) Probability of detection and correct classification of all valid Lofar gram signatures

3.4) Type: Evaluation of aircraft monitor plans for buoy patterns

3.4.1) MOE's Selected:

(a) Total time monitored
(b) Median length of monitor periods
(c) Average number of detections
(d) Mean monitoring time per detection
(e) Total detection time
(f) Median length of detection periods
(g) Percent of time detecting while monitoring

A. STUDY DESCRIPTION

1) Originating Activity: Cornell Aeronautical Laboratory, Inc. Buffalo, New York
2) Report Title: Open Ocean ASW Air-Sea Craft System Feasibility Study, Vols. I-VI
3) Report Number: GM-1968-G-1 (AD-507 543, AD-507 542, AD-507 576, AD-507 577, AD-507 578 and AD-507 536)
4) Date: 26 January 1965
5) Classification: Vols. I,II,IV,VI Secret and Vols. III,V Confidential
6) Contract: Nonr 4545(00) (Office of Naval Research)
7) Abstract: This study investigates the technical feasibility and cost effectiveness of open ocean air-sea craft weapon systems in antisubmarine operations. This is accomplished through six major study phases which consider: (1) the submarine threat in a specified time period, (2) the operational sea environment for air-sea craft, (3) the characteristics, performance and technical feasibility of air-sea craft vehicles and acoustic sensors, (4) the open ocean capabilities of air-sea craft, (5) the air-sea craft system effectiveness and cost in various ASW missions (barrier, task group and convoy screening, contact area investigation, and trailing operations), and (6) the critical technical problem areas associated with air-sea craft systems. The different types of air-sea craft vehicles examined in the study are: conventional takeoff and landing seaplanes (CTOL), short takeoff and landing seaplanes (STOL), vertical takeoff and landing air-sea craft (VTOL), and ground-effect takeoff and landing air-sea craft (GETOL).
8) Descriptors: Aircraft, antisubmarine warfare, barrier, contact investigation, convoy escort, cost, cost effectiveness, dipping sonar, missile, screen, sonobuoy, SOSUS, submarine, torpedo, trailing

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Airborne ASW
3) Applicable Situations:
   - 3.1) Type: Evaluation of vehicle design
     - 3.1.1) MOE's Selected:
       - (a) Ratio of useful load to takeoff gross weight, where useful load is defined as the takeoff gross weight minus operating weight empty
         - Rationale For Selection: This MOE provides a measure of structural efficiency.
       - (b) Cruise efficiency in nautical miles per pound of fuel
         - Rationale For Selection: This MOE provides a measure of the combined aerodynamic and propulsion performance.
       - (c) On-station airborne endurance
       - (d) On-station waterborne endurance
   - 3.2) Type: Evaluation of sonar performance
     - 3.2.1) Criterion For Success: Detection of target
     - 3.2.2) MOE Selected:
       - (a) Sonar detection range for specified probability of detection
   - 3.3) Type: Evaluation of air/sea craft performance in ASW missions
     - 3.3.1) MOE's Selected:
       - (a) Total number of aircraft necessary to perform the mission
       - (b) Number of sorties required to perform the mission
       - (c) Total mission cost which is defined as the sum of the basic mission (sortie) cost and the cost of carrier basins and refueling, buoy losses and weapons expended
       - (d) Total air/sea craft lifetime cost which is defined as the initial investment cost plus total annual operating cost

A. STUDY DESCRIPTION

1) Originating Activity: Planning Research Corporation, Washington, D.C.
2) Report Title: A Linear Programming Analysis of Antisubmarine Aircraft
3) Authors: R. McQuie, G. Hedlund, W. Montweiler, W.H. Schrader and J. Shiebler
4) Report Number: PRC R-1129 (AD-389 817)
5) Date: May 1968
6) Classification: Confidential
7) Contract: N00014-68-C-0181 (Office of the Chief of Naval Operations)
8) Abstract: This report describes a model of antisubmarine aircraft constructed around a linear programming algorithm. It stations carriers, land bases, and aircraft types to determine how many of which types are required at various locations to obtain the most destructive ASW system. For the ocean area under study, the effectiveness of a system based on land-based P-3 aircraft is analyzed and compared with a system based on carrier-based VS(X)'s.
9) Descriptors: Aircraft, antisubmarine warfare, cargo ship, carrier, carrier based aircraft, convoy escort, cost, detection, detection probability, force allocation, kill probability, linear programming, submarine, tanker ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force
2) Function: Airborne ASW
3) Applicable Situation: Determination of force mix to conduct submarine search in a specified ocean area
   3.1) Criterion For Success: Destruction of target
   3.2) MOE Selected:
      (a) Maximum probability of detecting and killing a submarine in a specified ocean area

MOE REVIEW NO. (1)-7

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Air Development Center, Johnsville, Pennsylvania
2) Report Title: Mission Analysis of Advanced Active Sensors
3) Authors: C.W. Van Wyk and D.H. Panetta
4) Report Number: NADC-SD-7169 (AD-519 445)
5) Date: 30 July 1971
6) Classification: Confidential
7) Project Number: AIRTASK A5335330/202C/W21400000 (Naval Air Systems Command)
8) Abstract: This report documents three mission analyses, and provides cost and performance data for use in updating the active sensor portion of TDP 2140. The missions were selected because of the ability of the active sensors to contribute to their success and because certain unique advantages of active sensors over passive sensors were made more visible.
9) Descriptors: Aircraft, antisubmarine warfare, contact investigation, destroyer, detection, dipping sonar, helicopter, localization, screen, sonobuoy, submarine, surface ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne ASW
3) Applicable Situation: Evaluation of the performance of an aircraft deployed sonobuoy pattern for contact investigation
   3.1) Criterion For Success: Detection of submarine
   3.2) MOE's Selected:
      (a) Maximum time to detection

(b) Number of buoys required for a specified probability of detection

(c) Probability that the submarine is contained in the area covered by the pattern

MOE REVIEW NO. (1)-8

A. STUDY DESCRIPTION

1) Originating Activity: Falcon Research and Development Company, Thor Division, Cockeysville, Maryland
2) Report Title: Inherent Vulnerability, Survival, and Protection Analyses of the S-3A Aircraft
3) Authors: W. J. Douglass, Jr., R. R. Rudolph and J H. Young
4) Report Number: Thor Report No. 72 (AD-508 001)
5) Date: February 1970
6) Classification: Secret
7) Contract: N62269-69-C-0498 (Naval Air Development Center)
8) Abstract: A presentation is given of the results of an analysis of the inherent vulnerability and survivability of the unprotected and protected S-3A aircraft. During this analysis three practical protection schemes were devised. Three missions, search and attack, contact investigation, and surface surveillance, are considered for encounters with selected ground-to-air and air-to-air defensive weapon threats. Component vulnerability areas and aircraft kill probability tables are presented.
9) Descriptors: Aircraft, air-to-air missile, antiair warfare, carrier, contact investigation, kill probability, surface ship, surface-to-air missile, surveillance, survivability, vulnerability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne ASW
3) Applicable Situation: Evaluation of the vulnerability and survivability of an aircraft against selected ground-to-air and air-to-air defensive weapon threats

3.1) Criterion For Success: Survival of aircraft

3.2). MOE's Selected:

(a) Probability of kill (in a given kill category; KK, K, A, B, C or E) of the aircraft by a specified weapon. The kill categories are defined as follows:

KK - Damage such that the aircraft will disintegrate immediately after the damage occurs

K - Damage such that the aircraft will fall out of control immediately after the damage occurs

A - Damage such that the aircraft will fall out of control within 5 minutes after damage occurs

B - Damage such that the aircraft will fall out of control within 30 minutes after damage occurs

C - Damage that will prevent the aircraft from completing its mission

E - Damage such that the aircraft will crash on landing

(b) Kill probability reduction per pound of protection

(3)

AIRBORNE ATTACK

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: The Effectiveness of A-1 Bombing Attacks on Bridges
3) Author: L. R. Heselton Jr.
4) Report Number: Operations Evaluation Group Study No. 688 (AD-362 078)
5) Report Date: 28 April 1965
6) Classification: Confidential
7) Contract: NONR 3732(00) (Office of Naval Research)
8) Abstract: This study determines the effectiveness of various A-1 aircraft payloads against bridges. The optimum load, regardless of bridge type is determined. The effects of different intervalometer settings and approach angles are also analyzed. Data for adjusting the effectiveness estimates to reflect variations in bridge size and delivery accuracy are also provided.
9) Descriptors: Airborne attack, aircraft, bomb, bridge, cost effectiveness

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne Attack
3) Applicable Situation: Evaluation of the effectiveness of bombing attacks on bridges

3.1) Criterion For Success: Destruction of target

3.2) MOE's Selected:

(a) Probability of collapse of at least one span when the weapons are dropped in a single pass

(b) Expected number of sorties required for the collapse of at least one span for all weapons delivered in a single pass

(c) Expected number of sorties required for the collapse of at least one span for all weapons delivered in two passes

MOE REVIEW NO. (3)-2

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Weapons Center Corona Laboratories, Corona, California
2) Report Title: Classified
3) Authors: G. R. Lanning, J. Y. K. Chang and E. A. King
4) Report Number: No. 71-54 (AD-387 279)
5) Report Date: 19 February 1968
6) Classification: Confidential
7) Abstract: A cost effectiveness analysis is made of two weapon configurations, In performing the analysis, a computer program was used to compute both delivery costs and weapon effectiveness in destroying a number of representative targets.
8) Descriptors: Aircraft, air-to-surface missile, attrition, cost effectiveness, kill probability, target mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne Attack
3) Applicable Situation: Evaluation of air-delivered weapon performance against a mix of ground targets
   3.1) Criterion For Success: Destruction of target
   3.2) MOE Selected:
      (a) Cost effectiveness, which is defined as the ratio of the target value destroyed to total costs incurred, which include weapon procurement cost, weapon RDT&E costs (amortized over the weapon buy level), aircraft operating costs, and replacement cost for aircraft lost due to attrition by enemy defensive systems. The tar-

get value destroyed is defined as the kill probability achieved against each target, multiplied by the target's assigned military value.

MOE REVIEW NO. (3)-3

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Weapons Selection for Attacks by Naval Air Upon Tactical Targets
3) Report Number: OEG Report 65 (AD-500 472)
4) Date: 7 November 1951
5) Classification: Confidential
6) Abstract: This report is intended to summarize the available information on the weapons best suited to, and the forces required for attack by Naval Air on bridges, airfields, transportation targets, and close-support targets.
7) Descriptors: Airborne attack, aircraft, bomb, close air support, hit probability, kill probability, target mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Airborne Attack
3) Applicable Situations:
   3.1) Type: Evaluation of bombs in the destruction of bridges
      3.1.1) Criterion For Success: Collapse of at least one span of the bridge
      3.1.2) MOE Selected:
         (a) Expected number of aircraft sorties required for a given probability of success
   3.2) Type: Evaluation of bombs in the neutralization of airfields
      3.2.1) Criterion For Success: Temporary denial of enemy use of his bases and attrition of enemy aircraft and breakdown of facilities

3.2.2) MOE Selected:

(a) Expected number of bombs required for a specified duration of airfield neutralization

3.3) Type: Evaluation of bombs in attack of transportation targets

3.3.1) Criterion For Success: Temporary denial of a transportation route to the enemy and attrition of vehicles

3.3.2) MOE Selected:

(a) Expected number of bombs required for a specified assurance of target destruction

3.4) Type: Evaluation of bombs in attack of close support targets

3.4.1) Criterion For Success: Deprive enemy of services of troops and/or affect morale of troops and civilians

3.4.2) MOE Selected:

(a) Expected number of sorties for a specified level of success

MOE REVIEW NO. (3)-4

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Postgraduate School, Monterey, California
2) Report Title: An Analysis of the Factors Effecting the Probability of Survival for Carrier Pilots in a Combat Environment
3) Author: R.M. Hart
4) Report Identification: Thesis for the Masters of Science in Operations Research, (AD-512 625)
5) Date: September 1970
6) Classification: Secret
7) Abstract: The thesis establishes the existence of a relationship between rank, number of combat sorties and probability of survival for carrier pilots in a combat environment. The experience obtained over North Vietnam provides the input data. Many variables and their associated data needs are discussed, and the analysis is performed on the selected variables after the need for separating the data by squadron type is established.
8) Descriptors: Airborne attack, attrition, carrier, carrier based aircraft, survivability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Airborne Attack
3) Applicable Situation: Evaluation of the survivability of carrier pilots in combat environment
   3.1) Criterion For Success: Pilot survival
   3.2) MOE's Selected:
      (a) Pilot attrition probability for a single combat mission
      (b) Pilot attrition probability for a specified number of combat sorties
      (c) Number of pilot attritions for a specified sortie rate

(d) Number of pilot attritions for a specified number of missions

(e) Number of pilot attritions for a specified number of months of combat

MOE REVIEW NO. (3)-5

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Nuclear Bullpup vs. Unguided Nuclear Weapons: Comparative Effectiveness in Limited War
3) Report Number: OEG Study No. 638
4) Date: 28 October 1960
5) Classification: Secret
6) Abstract: This study compares the effectiveness of a short-range air-to-surface nuclear missile (ASM) with unguided nuclear weapon delivery against likely limited war targets
7) Descriptors: Airborne attack, aircraft, air-to-surface missile, kill probability, nuclear warhead, target mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Airborne Attack
3) Applicable Situation: Evaluation of the effectiveness of air-to-surface nuclear weapons against various targets
   3.1) Criterion For Success: Destruction of target
   3.2) MOE's Selected:
      (a) Target kill probability, which for a point or line target is the probability that the circle of destruction covers the desired ground zero, and for an area target is the average fraction of the total area destroyed by one drop
      (b) Yield required to kill a specified percent of targets attacked

MOE REVIEW NO. (3)-6

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Weapons Center, China Lake, California
2) Report Title: Tactical Air Armament Study Part II Phase 1B Vols. I, II
3) Report Number: NWC Document 12-803
4) Date: May 1970
5) Classification: Secret
6) Abstract: Phase 1A concentrated attention on current weapon systems and near-term solutions to problems. As a result, a number of requirements for additional study in specific areas were identified. This report then is a presentation of a set of rather independent analyses and discussions that bear on important aspects of naval air warfare.
7) Descriptors: Airborne attack, aircraft, bomb, mining, rocket, target mix, vulnerability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Airborne Attack
3) Applicable Situations:
   3.1) Type: Evaluation of aircraft weapon systems effectiveness on a mix of surface targets
      3.1.1) Criterion For Success: Destruction of target
      3.1.2) MOE's Selected:
         (a) Probability of target kill as a function of delivery accuracy
         (b) Expected number of weapon units required per kill
         (c) Expected whole number of passes per kill
   3.2) Type: Evaluation of aircraft loadout and carriage capabilities
      3.2.1) MOE's Selected:
         (a) Number of bombs carried per aircraft as a function of bomb weight
         (b) Tons delivered on target per aircraft sortie as a function of bomb weight

3.3) Type: Evaluation of bomb effectiveness against a mix of surface targets

3.3.1) Criterion For Success: Destruction of target

3.3.2) MOE Selected:

(a) Mean area of effectiveness as a function of burst height

3.4) Type: Evaluation of air-delivered weapon performance against a mix of hard targets

3.4.1) Criterion For Success: Destruction of target

3.4.2) MOE's Selected:

(a) Weapon penetration required to achieve a specified kill level

(b) Probability of target kill given a hit

(c) Pounds of explosive required at specified penetration depth to kill target

3.5) Type: Evaluation of the effectiveness of area denial weapons

3.5.1) Criterion For Success: Damage or delay enemy personnel or material

3.5.2) MOE's Selected:

(a) Expected number of potential casualties

(b) Expected number of virtual casualties

MOE REVIEW NO. (3)-7

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Research Laboratory, Washington, D.C.
2) Report Title: Technical Requirements and Cost Effectiveness Study for U.S. Naval Limited War Systems, Part II - Analytical Solution for ASM
3) Report Number: NRL Memorandum Report 1579 (AD-357 387)
4) Date: October 1964
5) Classification: Secret (NOFORN)
6) Abstract: This report describes the effort being conducted under a program having the objective of establishing the methodology for dealing with advanced weapon systems concepts. A current problem of interest (air-to-surface missile systems) is utilized to demonstrate the procedure by which accomplishment of the end objective can be achieved. A "first cut" of the Part II - Analytical Solution was published in NRL Memo Report 1399. The material detailed here is intended as a supplement to that report.
7) Descriptors: Airborne attack, aircraft, air-to-surface missile, antiaircraft defense, antiaircraft gunnery, bomb, hit probability, kill probability, missile seeker, radar, rocket, surface target, surface-to-air missile, survivability, target acquisition, target mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Airborne Attack
3) Applicable Situations:
   3.1) Type: Evaluation of the effectiveness of attack aircraft in a penetration raid against surface targets defended by air defenses

3.1.1) Criterion For Success: Destruction of target and survival of aircraft

3.1.2) MOE's Selected:

(a) Probability that the target is destroyed

(b) Probability that the attacking aircraft survives

3.2) Type: Evaluation of the effectiveness of an airborne target tracking sensor

3.2.1) Criterion For Success: Acquisition of target

3.2.2) MOE Selected:

(a) Probability of acquisition of the target

3.3) Type: Evaluation of the performance of an air-to-surface missile guidance system

3.3.1) Criterion For Success: Acquisition of target

3.3.2) MOE's Selected:

(a) Probability of terminal seeker acquisition of target

(b) Probability of missile successfully settling

(c) Expected terminal miss distance of missile

MOE REVIEW NO. (3)-8

A. STUDY DESCRIPTION

1) Originating Activity: Office of the Chief of Naval Operations, Washington, D.C.
2) Report Title: Tactical Air Armament Study -- Fiscal Year 71 (TAAS-71) Vol. I-III
3) Authors: W.B. Muncie, J.R. Foster, R.F. Rowntree, D.F. Kusterer and W.E. Stump
4) Report Number: (AD-520 176, AD-520 177 and AD-520 178)
5) Date: December 1971
6) Classification: Secret (NOFORN)
7) Abstract: This and the previous TAAS studies have the objective of examining in detail the existing and planned weapon systems for the period 1972-1979, and determining the non-nuclear armaments that most effectively cover the targets and tactical situations for which Naval Air can expect to have mission responsibility. Previous phases of the study concentrated on near-term solutions to problems, recommended improvements for non-nuclear weapons, hardware, avionics, fire control and support equipment, and proposed a Tactical Air Armament Plan (TAAP) that provided a sound basis for non-nuclear Tactical Air Weapon Systems development and procurement. This report contains the recommended TAAP for the period FY 72 to FY 79 and a set of seven supporting analyses which are as follows: (1) enemy ship vulnerability, (2) weapons for defeating hard targets, (3) advanced aircraft rocket systems, (4) cluster munitions, (5) alternative trackers for angular-rate bombing systems, (6) implications of the TAAP for future attack aircraft, and (7) reconnaissance for Naval air strikes.
8) Descriptors: Airborne attack, aircraft, air-to-surface missile, bomb, close air support, cost, damage assessment, data link, hit probability, infrared sensor, kill probability, laser sensor,

optical sensor, radar, rocket, surface ship, target acquisition, target mix, torpedo, warhead

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Airborne Attack
3) Applicable Situations:
   3.1) Type: Evaluation of missile guidance and control subsystem performance
      3.1.1) Criterion For Success: Acquisition of target
      3.1.2) MOE's Selected:
         (a) Probability of target acquisition
         (b) Probability of continuous lock-on
         (c) Probability of successful control section operation
         (d) Probability of successful guidance
         (e) Probability of a hit
   3.2) Type: Evaluation of the vulnerability of combatant ships to air-delivered weapons
      3.2.1) MOE's Selected:
         (a) Probability of firepower damage, which is defined as the probability of loss of any key component or combination of key components in the surface ship weapon system that results in the ship being unable to effectively fire or control a weapon

            Rationale For Selection: Firepower kill is stressed when efforts to sink enemy ships, which would be eventually required, might take too much time and too many fleet resources. If a firepower kill could be obtained, a seaworthiness or sink kill could be executed from a shorter slant range with general purpose bombs and other less expensive weapons, with a relatively minor threat from the ship defenses.

(b) Probability of seaworthiness damage, which is defined as the probability the enemy ship will sink within an hour after attack

(c) Kill probability

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Weapons Center, China Lake, California
2) Report Title: Harrier Aircraft for Amphibious Air Fire Support
3) Author: F.G. Buffum
4) Report Number: Tech Note 12-70-4
5) Date: October 1970
6) Classification: Secret
7) Abstract: This report represents an exploratory effort being made to investigate the nature and scope of the general air fire support problem. Because of time limitations, effort has focused on the new Harrier VTOL light attack aircraft, the A-8A, in the amphibious assault sub-area of air fire support, including its possible roles, capabilities, and limitations as representative of high-performance V/STOL technology.
8) Descriptors: Airborne attack, aircraft, amphibious operation, availability, close air support, rescue, survivability, target mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne Attack
3) Applicable Situations:
   3.1) Type: Evaluation of aircraft performance in close air support missions
      3.1.1) MOE's Selected:
         (a) Aircraft availability, which is defined as the ratio of the number of aircraft available for the mission to the number of aircraft needed for the mission

(b) Timeliness of aircraft's response, which is defined as the ratio of aircraft response time to target "shelf life"

(c) Ratio of the weapon load carried by the aircraft to the weapon load needed for mission

(d) Ratio of aircraft ordnance delivery mode to delivery capability needed

(e) Overall effectiveness index (firepower), which is defined by:

$$\frac{\left(\frac{\text{No. of aircraft available}}{\text{No. of aircraft needed}}\right)\left(\frac{\text{Aircraft weapon load}}{\text{Weapon load needed}}\right)\left(\frac{\text{Aircraft delivery mode}}{\text{Delivery desired}}\right)}{\left(\frac{\text{Aircraft response time}}{\text{Target "shelf life"}}\right)}$$

(f) Average number of sorties per aircraft per day

3.2) Type: Evaluation of aircraft ordnance carrying capability in close air support missions

3.2.1) Criterion For Success: Destruction of target

3.2.2) MOE Selected:

(a) Percent of close air support attack sorties for which an expected target kill is achieved at or below a specified weapon weight

3.3) Type: Determination of aircraft utilization

3.3.1) MOE Selected:

(a) Average utilization per aircraft per month

3.4) Type: Evaluation of aircraft performance in a rescue mission

3.4.1) Criterion For Success: Rescue of wounded personnel

3.4.2) MOE Selected:

(a) Survival probability of seriously wounded personnel in enemy territory as a function of the distance rescue aircraft must fly

(5)

MINING

MOE REVIEW NO. (5)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center For Naval Analyses, Arlington, Virginia
2) Report Title: Criteria for Aerial Minelaying Accuracy
3) Author: D. F. Mela
4) Report Number: OEG Study 521
5) Date: 24 February 1954
6) Classification: Confidential
7) Abstract: This study is concerned with methods of describing and evaluating the results of aerial minelaying training exercises and practice drops. Statistical measures for assessing the results of minelaying exercises are also discussed.
8) Descriptors: Aircraft, mining, statistics

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Mining
3) Applicable Situation: Evaluation of minelaying accuracy
   3.1) Criterion For Success: Accurate minelaying
   3.2) MOE's Selected:
      (a) Percentage of drops within a specified distance from a target line

         Rationale For Selection: This is a measure of the ability to mine a channel, since the errors of importance are those in a direction perpendicular to the channel centerline.

      (b) Percentage of errors exceeding four times the median error

Rationale For Selection: This is a measure of the prevalence of gross errors and can be used to test the presence of too many large errors.

(c) The bias index for errors measured from the target line

Rationale For Selection: This measure provides a check on whether or not there exists a significant tendency to drop mines long or short (right or left) of the channel.

MOE REVIEW NO. (5)-2

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Ordnance Laboratory, White Oak, Maryland
2) Report Title: Delay as a Measure of Mine Effectiveness
3) Author: W.C. Wineland
4) Report Number: NOLTR 69-206 (AD-507 922)
5) Date: 30 November 1969
6) Classification: Confidential
7) Abstract: The conventional measure of minefield effectiveness is in terms of target ships sunk or damaged. It is well known that minefields can, and frequently do, produce other effects than damage. One such effect is a delay in ship operations which may be caused, for example, by countermeasures operations on the minefield or by re-routing ships by alternate, longer routes to avoid the minefield. If the ships delayed by the minefield are engaged in repetitive operations, the effect of the delay can be expressed in terms of virtual ship attrition, i.e., an effective reduction in the total force of ships engaged in the mission. Several examples are given.
8) Descriptors: Mine, mining, submarine, surface ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Mining
3) Applicable Situation: Evaluation of minefield effectiveness
   3.1) Criterion For Success: Reduction in the total ship force engaged in a mission

3.2) MOE Selected:

(a) Delay or lost-time per cycle due to minefield presence

Rationale For Selection: The rationale for delay as an effectiveness measure is apparent if one considers the situation when a minefield is encountered. The commander, or other responsible authority, makes some estimate of the extent of the field and the number of mines in it, and from this, the threat of the field or the probability that a ship attempting to transit the field will be sunk or suffer some lesser degree of damage. The alternatives to attempting a transit are to interrupt traffic while countermeasures are employed to reduce the field, or to re-route traffic around the field; in either case the penalty is a delay in ship traffic. Thus, the commander must weigh the cost of ship damage against the cost of delay.

(6)

MINE COUNTERMEASURES

MOE REVIEW NO. (6)-1

A. STUDY DESCRIPTION

1) Originating Activity: Naval Schools, Mine Warfare Naval Base, Charleston, South Carolina
2) Report Title: A Case for the Continuation of the Surface Minecraft
3) Author: D.H. Porter
4) Report Number: NSMW TP 57 (AD-518 685)
5) Date: 30 November 1971
6) Classification: Confidential
7) Abstract: An evaluation of the effect on mine countermeasures readiness occasioned by the transition from surface to airborne mine sweepers, with cost of tactics comparisons, discussions of strengths and weaknesses, and presentation of the corollary case for the continuation of an improved new construction surface mine craft.
8) Descriptors: Cost, cost effectiveness, helicopter, mine sweeper, minesweeping

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Mine Countermeasures
3) Applicable Situation: Evaluation of a minesweeping unit
   3.1) Criterion For Success: Clearance of minefield
   3.2) MOE's Selected:
      (a) Sweep rate
      (b) Cost per swept mile

MOE REVIEW NO. (6)-2

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Ship Research and Development Laboratory, Panama City, Florida
2) Report Title: Minesweeper/Minehunting Effectiveness Study
3) Author: G.C. Watkins
4) Report Number: Report C2900 (AD-511 688)
5) Date: March 1969
6) Classification: Confidential
7) Abstract: This study was based on the primary mission of the MSO (Minesweeper, Ocean-nonmagnetic) of providing mine countermeasures in the minefields of the amphibious objective area for a large amphibious assault. The study evaluates the effectiveness of variations and trade-offs of the following mine countermeasures ship system characteristics: (a) ship's acoustic signature, (b) acoustic minesweeping capability, (c) shock resistance, (d) magnetic minesweeping capability, (e) ship's magnetic signature, (f) sweeping speed, and (g) ship size. A computerized allocation of resources model was used to select optimum tactics for both the miner and the mine countermeasures forces.
8) Descriptors: Amphibious operation, attrition, cost, game theory, mine, mine countermeasure, minehunting, minesweeping, mining, Monte Carlo method, surface ship, survivability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Mine Countermeasures
3) Applicable Situations:
   3.1) Type: Evaluation of minecraft performance using mine countermeasures in a minefield

3.1.1) Criterion For Success: Clearance of minefield

3.1.2) MOE's Selected:

(a) Number of minecraft required to accomplish a specified mine countermeasures task

(b) Total dollar cost of mine casualties resulting when a fixed force is employed

3.2) Type: Evaluation of minesweeper/minehunter vulnerability to mine explosions

3.2.1) MOE's Selected:

(a) Aggregate (sweeper or hunter) damage width

Limitations And Assumptions

(1) The aggregate damage width is primarily a function of ship construction, minesweeping currents, and degaussing, and does not include the effect of the sweep field.

(b) Probability of immobilizing damage

3.3) Type: Evaluation of sweeping effectiveness

3.3.1) Criterion For Success: Clearance of minefield

3.3.2) MOE Selected:

(a) Ratio of aggregate damage width of the sweeper to aggregate sweep actuation width

Rationale For Selection: For a large number of ship-mine encounters this exchange ratio is a good measure of expected minesweeper losses.

(7)

OCEAN SURVEILLANCE

MOE REVIEW NO. (7)-1

A. STUDY DESCRIPTION

1) Originating Activity: Planning Research Corporation, Los Angeles, California
2) Report Title: The Technical Evaluation and Cost Analysis of the Deep-Water Moored Buoy ASW System P-499, Vol. I Summary and Vol. II Analysis and Appendices
3) Authors: J. H. Herd, P. K. Luster, R. E. Morris and W. J. Smith
4) Report Number: PRC R-654 (AD-364 281 and AD-365 022)
5) Date: 30 July 1965
6) Classification: Secret
7) Contract: NOw-64-0374 (Bureau of Naval Weapons)
8) Abstract: This report contains a systems analysis and operations research study of system P-499. System P-499 is an ASW surveillance system which utilizes a field of deep water-moored buoys linked to data processing and analysis centers by a satellite relay communications link. The purposes of this study were to analyze the system P-499, to perform a cost-effectiveness study of the system, and to compare system P-499 effectiveness with that of other systems.
9) Descriptors: Aircraft, antisubmarine warfare, barrier, binomial density function, buoy, cost, cost effectiveness, normal density function, Poisson density function, satellite, submarine, surveillance

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Ocean Surveillance
3) Applicable Situations:
   3.1) Type: Evaluation of the performance of a sonobuoy barrier
      3.1.1) MOE's Selected:
         (a) Effectiveness of the barrier, which is defined to be the product of buoy reliability times a

weighted sum of the probability of detection, classification, track and localization

(b) Specific effectiveness index, which is defined as the ratio of the effectiveness of the barrier to the number of buoys in the barrier

Rationale For Selection: This MOE can be considered as a measure of effectiveness per buoy.

(c) Number of buoys required for a barrier for specified probabilities of detection, track and containment

(d) Expected number of buoys required for the installation and maintenance of a barrier over a given time period

3.2) Type: Evaluation of the effectiveness of a satellite communication system

3.2.1) MOE's Selected:

(a) Probability of system communication during one orbit

(b) Probability of ground station-to-satellite communication

(c) Probability of satellite-to-sensor communication

(d) Probability of sensor-to-satellite communication

(e) Probability of satellite-to-ground station communication

3.3) Type: Evaluation of satellite monitoring of a buoy barrier

3.3.1) MOE's Selected:

(a) Satellite communication time, i.e., the time the satellite is in communication view of the buoy

(b) Effectiveness of satellite coverage of a barrier, which is defined as the ratio of the time available to obtain data to the time required to obtain all data

(c) Number of satellites required to monitor a given buoy configuration for a specified effectiveness of satellite coverage

(d) Percentage of buoys that can be interrogated by a satellite

(e) Effectiveness of satellite coverage of a barrier, as measured by the success in obtaining the data available in the effective length of a barrier in the swath of the satellite

3.4) Type: Evaluation of the performance of a satellite support system

3.4.1) MOE's Selected:

(a) Time required to establish a specified number of operational satellites in orbit

(b) Expected number of launchings required to establish and maintain a satellite system for a specified period of time

(c) Utilization factor on the launch pad to maintain satellite system

(d) Probability of successfully launching an operating satellite

3.5) Type: Evaluation of aircraft capability to lay sonobuoys

3.5.1) MOE's Selected:

(a) Average time required to lay a buoy successfully

(b) Average laying time per buoy

(c) Reliability of lay

MOE REVIEW NO. (7)-2

A. STUDY DESCRIPTION

1) Originating Activity: Planning Research Corporation, Los Angeles, California
2) Report Title: A Summary Report of Cost and Effectiveness of Selected Ocean-Area Surveillance Systems
3) Author: A. W. Corry
4) Report Number: PRC R-454 (AD-349 417)
5) Date: 31 December 1963
6) Classification: Secret
7) Abstract: Results of a two-phase study dealing with methods of achieving ocean-area surveillance are presented in summary form. Emphasis is given to the use of satellites and aircraft for performing surveillance. Comparisons among the systems analyzed are made in terms of both cost and effectiveness.
8) Descriptors: Aircraft, cost, cost effectiveness, radar, satellite, surveillance

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Ocean Surveillance
3) Applicable Situations:
   3.1) Type: Evaluation of a satellite system used in ocean surveillance
      3.1.1) MOE's Selected:
         (a) Cost effectiveness, which is defined as the 15 year cost of the system necessary to maintain a specified percent coverage of worldwide shipping
         (b) Total system cost for a specified operating life and probability of successful orbit

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Radiological Defense Laboratory, San Francisco, California
2) Report Title: Project Ocean Scan - A Study of the Utility of Satellite Imagery in Ocean Surveillance, Vol. 2 - Methodology for Requirements Analysis and System Synthesis
3) Authors: I.H. Zigman, E.P. Cooper, D.C. Campbell and C.W. Kelly, III
4) Report Number: USNRDL-TRC-22, Vol. 2 (AD-519 642)
5) Date: 16 August 1966
6) Classification: Secret
7) Project Number: WEPTASK No. RT 7045018/4501/F019-05-02 (Bureau of Naval Weapons)
8) Abstract: The objective of this report is to structure an approach to the analysis of the global sea surveillance mission; it is limited to the recommendation of methods useful in achieving an optimal solution. General procedures are provided for requirements analysis, system synthesis, and system evaluation. System performance, availability, utilization, and cost are emphasized; approaches are given for determining appropriate measures of system effectiveness.
9) Descriptors: Aircraft, availability, classification probability, cost, cost effectiveness, data link, detection probability, information theory, infrared sensor, localization, optical sensor, radar, reliability, satellite, SOSUS, surface ship, surveillance, tracking

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Ocean Surveillance

3) Applicable Situations:

3.1) Type: Evaluation of detection capability of a surveillance system

3.1.1) Criterion For Success: Detection of target

3.1.2) MOE's Selected:

(a) Probability of correct detection decision

Rationale For Selection: This is a measure of detection success and also an estimate of the percentage of time that the system makes a correct decision.

(b) Number of targets found per hour within R miles of the search vehicle

(c) Probability of target detection in the surveillance area

(d) Mean delay time in target detection after it has arrived in the surveillance area

(e) Cumulative probability of detection after n observations

3.2) Type: Evaluation of localization capability of a surveillance system

3.2.1) Criterion For Success: Localization of target

3.2.2) MOE's Selected:

(a) Maximum area of uncertainty, which is defined as the circle in which the target is located with a specified percent confidence

(b) Probability of localization within a specified radius from actual location with a specified percent confidence

3.3) Type: Evaluation of the classification capability of a surveillance system

3.3.1) Criterion For Success: Classification of target

3.3.2) MOE Selected:

(a) Probability of correctly classifying a detected target within a specified time after detection with a specified percent confidence

3.4) Type: Evaluation of the tracking capability of a surveillance system

3.4.1) Criterion For Success: Establishment and maintenance of track over a period of time

3.4.2) MOE's Selected:

(a) Probability of predicting target location within a specified radial accuracy with a specified percent confidence

(b) Probability of establishing a track as a function of time

(c) Ratio of the number of ships in the surveillance area to the number tracked

(d) Average holding time of a track

(e) Ratio of losing contacts to average holding time

(f) Probability of regaining a contact

(8)

SUBMARINE ASW

MOE REVIEW NO. (8)-1

A. STUDY DESCRIPTION

1) Originating Activity: Submarine Development Group Two, Groton, Connecticut
2) Report Title: Submarine Analyses Notebook
3) Date: 24 October 1968
4) Classification: Confidential
5) Abstract: This report discusses the development of methodologies and operations analysis techniques for evaluation of submarine weapons system performance in several operational concepts. It is primarily designed as a reference document for military and civilian analysts who are actively engaged in evaluating submarine performance. While it provides a documentation of analysis techniques currently in use, it will be modified and extended as these techniques are refined and/or new formulations developed.
6) Descriptors: Antisubmarine warfare, barrier, detection probability, false target, kill probability, kill rate, sonar, submarine, transitor, vulnerability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Submarine ASW
3) Applicable Situations:
   3.1) Type: Evaluation of the tactical situation involving SSK versus Transitor
      3.1.1) Criterion For Success: Suppression of submarine activity
      3.1.2) MOE's Selected:
         (a) Probability of killing a transiting submarine,

referred to as Weapons System Effectiveness (WSE)

(b) Probability of being killed by an enemy submarine transiting the SSK patrol area, referred to as Weapon System Vulnerability (WSV)

(c) Exchange ratio, defined as the expected number of transitors killed per SSK lost

3.2) Type: Evaluation of the performance of a submarine in the Intruder role

3.2.1) Criterion For Success: Seek out and destroy, or gain intelligence of, an enemy submarine in its own patrol area

3.2.2) MOE's Selected:

(a) Kill rate, defined as the rate at which enemy targets are killed as a function of the Intruder area size

(b) Probability that the Intruder will detect a target present in a specified area as a function of time

(c) Probability that the Intruder will kill the target given that he has detected the target

(d) Expected number of targets killed for each Intruder killed

(e) Number of square miles per day which the Intruder can effectively search, i.e. the search rate

(f) Effective sonar sweep width

(g) False alarm ratio, defined as the ratio of the number of non-submarine contacts or friendly submarine contacts which are classified enemy submarine to the total number of sonar contacts

(h) Wrong identification ratio, defined as the ratio of the number of friendly submarines

identified as enemy submarines to the total number of friendly submarines detected

(i) False attack ratio, defined as the ratio of the number of non-submarine sonar contacts or friendly submarine contacts which are prosecuted to an attack, and which would have or did result in the expenditure of a weapon by the Intruder, to the total number of sonar contacts

MOE REVIEW NO. (8)-2

A. STUDY DESCRIPTION

1) Originating Activity: Daniel H. Wagner, Associates, Paoli, Pennsylvania
2) Paper Title: "Secure Sweep Width as a Measure of Detection Effectiveness"
3) Authors: D. H. Wagner and E. P. Loane
4) Source: U. S. Navy Journal of Underwater Acoustics, Vol. 19 No. 2 (AD-504 550)
5) Date: April 1969
6) Classification: Confidential
7) Contract: NObs-921 46 and Nonr-4784(00) (Office of Naval Research)
8) Abstract: Secure sweep width (SSW) is a measure of effectiveness which gauges a submarine's ability to detect without prior counter-detection; it combines acoustic, kinematic, and probabilistic effects. This measure is the result of an adaptation of the classical concept of sweep width. Its general usefulness is discussed together with the related measure, secure sweep rate. A basic method is presented for predicting this measure. This applies to the simplest case: nuclear versus nuclear with own ship hovering. Kinematic enhancement from own ship's motion is reflected by a multiplicative correction. Complications from diesels are noted, but are not treated here. Applications to optimization of tactics are given: Patrol speed is chosen to maximize SSW, as a tradeoff between the acoustic degradation and kinematic enhancement attending the use of high speeds. As a two person game, a minimax pair of transit and patrol speeds are chosen with SSW as payoff.
9) Descriptors: Antisubmarine warfare, detection, game theory, normal density function, sonar, submarine, transitor

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Submarine ASW
3) Applicable Situation: Evaluation of the effectiveness of a SSK submarine assigned to cover a frontage against which enemy submarines attempt to penetrate or to transit past
   3.1) Criterion For Success: Obtain secure detection of submarine
   3.2) MOE's Selected:
      (a) Secure sweep width, which is defined as the area under the secure detection lateral range curve; that is, the area under the graph of the probability that the SSK makes a secure detection (a detection which has not been preceded by counterdetection by the target) at some point during the intruder's pass

         Rationale For Selection: This measure gauges a submarine's ability to detect without prior counter-detection, and it combines a variety of acoustic, kinematic, and probabilistic effects into a single number. This number may be used to compare one ship against another or one tactic against another, as well as to estimate force requirements for detection purposes.

      (b) Secure sweep rate, which is defined as the secure sweep width times the search rate

         Limitations And Assumptions:

            (1) This measure is applied to a submarine searching an extensive region (rather than covering a frontage) for a target hiding in this region.

      (c) Average number of secure detections

MOE REVIEW NO. (8)-3

A. STUDY DESCRIPTION

1) Originating Activity: U. S. Naval Weapons Laboratory, Dahlgren, Virginia
2) Report Title: Methodology for a Submarine Weapons Endurance and Effectiveness Study, the Submarine Weapons Expenditure Model
3) Authors: O. K. Blosser and R. L. Fausey
4) Report Number: NWL TR-2289 (AD-502 570)
5) Date: May 1969
6) Classification: Confidential
7) Abstract: The Submarine Weapons Encounter Model (SWEM) is a Monte Carlo type of computer model programmed in FORTRAN IV for the IBM 7030 computer. The model addresses itself to mounting a submarine barrier patrol in which various targets are engaged in the patrol area. The SWEM deals with sequential events, independent of time, in which a random number is drawn from a uniform distribution and compared with conditional probabilities to determine occurrence (or non-occurrence) of each event. One replication of the model consists of the entire enemy force (composed of an input number of targets) which attempts to penetrate the barrier patrol area in a sequence where one engagement does not interfere with the next. Each game is replicated a sufficient number of times so that statistically significant results are achieved. Major outputs to each model replication include (a) number of targets detected, (b) number of targets killed, (c) number of each weapon type expended, and (d) survival data on the barrier submarine.
8) Descriptors: Antisubmarine warfare, barrier, detection, kill, Monte Carlo method, submarine

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Submarine ASW
3) Applicable Situation: Evaluation of the performance of a submarine in the forward area barrier mission
   3.1) Criterion For Success: Detection and/or destruction of submarine
   3.2) MOE's Selected:
      (a) Expected number of targets detected
      (b) Expected number of targets killed

MOE REVIEW NO. (8)-4

A. STUDY DESCRIPTION

1) Originating Activity: Daniel H. Wagner, Associates, Paoli, Pennsylvania
2) Report Title: SSK Effectiveness Using Active/Passive Search and Tradeoffs With Passive-Only Search
3) Authors: B. Belkin and E.P. Loane
4) Report Number: DHWA Log No. 20-1335 (AD-393 474)
5) Date: 28 August 1968
6) Classification: Secret
7) Contract: N60921-68-C-0031 (ASW Systems Project Office)
8) Abstract: This report presents results of analyses undertaken to examine the effectiveness of alternative characteristics of active search sonars for an SSK in the forward area search and attack mission. The operational performance of the SSK, in terms of probabilities of kill and counterkill, is determined as a function of the performance of the search sonar. A number of ancillary questions, such as the effect of active search sonar scan rate, self-noise reduction, and target type, are answered quantitatively. The results allow the translation of requirements for SSK effectiveness into requirements for the search sonar, either active or passive. In addition, they allow the examination of a number of tradeoffs in sonar system design, and the tradeoff between active and passive search capabilities is expressly addressed.
9) Descriptors: Antisubmarine warfare, barrier, detection, game theory kill probability, Lanchester equations, normal density function, sonar, submarine, torpedo, tracking

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Submarine ASW

3) Applicable Situation:

3.1) Type: Evaluation of SSK performance in a forward area search and attack mission

3.1.1) Criterion For Success: Detection and destruction of submarine

3.1.2) MOE Selected:

(a) Probability that on a given transit the SSK kills the transitor minus three times the probability that the transitor kills the SSK

Rationale For Selection: The results of this analysis allows a number of cost-effectiveness tradeoffs to be examined. The weighting of probability of kill and counterkill is a reflection of the fact that the SSK's mission is not to intercept and kill a single transitor, but to intercept and kill as many of a sequence of transitors as possible. The SSK's performance in this latter respect depends very strongly on its ability to survive an encounter. If, when considering relative force levels, one is willing to trade one SSK for three transitors and unwilling to trade at any lower ratio, then the optimal tactic and search mode for the SSK is one which maximizes this MOE.

3.2) Type: Evaluation of SSK performance in a barrier campaign

3.2.1) Criterion For Success: Prevention of enemy transits of barrier

3.2.2) MOE Selected:

(a) Expected number of successful enemy transits during the campaign

3.3) Type: Evaluation of the SSK versus Transitor encounter

3.3.1) MOE's Selected:

(a) Probability that SSK kills transitor given the SSK is not being tracked at the firing circle and given an SSK approach

(b) Probability that SSK kills transitor given the SSK is being tracked at the firing circle and given an SSK approach

(c) Probability that transitor kills SSK given the SSK is not being tracked at the firing circle and given an SSK approach

(d) Probability that transitor kills SSK given the SSK is being tracked at the firing circle and given an SSK approach

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Ordnance Laboratory, White Oak, Maryland
2) Report Title: Advanced Submarine Weapon System Studies
3) Author: L.C. Fisher
4) Report Number: NOLTR 69-198 (AD-518 460)
5) Date: 17 November 1969
6) Classification: Secret
7) Abstract: This report reviews and summarizes studies of advanced submarine weapon systems. These studies include long range, quick reaction nonnuclear missile type antisubmarine and antiship weapons for use from 21-inch torpedo tubes as well as larger size weapons having greater effectiveness.
8) Descriptors: Antisubmarine warfare, cost, hit probability, kill probability, missile, reliability, submarine, submarine attack, surface ship, underwater-to-underwater missile, warhead

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Submarine ASW
3) Applicable Situation: Evaluation of antisubmarine missile system
   3.1) MOE Selected:
      (a) Total kill probability, defined as the product of reliability, probability of hit, and the probability of kill given hit

(10)

SURFACE ASW

MOE REVIEW NO. (10)-1

A. STUDY DESCRIPTION

1) Originating Activity: Raff Analytic Study Associates, Inc., Silver Spring, Maryland
2) Report Title: Passive and Active Escort Sonar Performance
3) Authors: J. E. Scheu, J. I. Bowen and E. L. Sander
4) Report Number: CR-1-160 (AD-515 787)
5) Date: October 1970
6) Classification: Confidential
7) Contract: N00024-69-C-1319, Subcontract 160-69-7 (Department of the Navy, Naval Ships System Command)
8) Abstract: The performance of an escort vessel in screening a task force from submarine penetration has been examined with the aim of studying the enhancement which a passive sonar offers the active sonar in carrying out detection and classification. A computer simulation of an encounter between a task force and a submarine was created for this purpose. The requirements of the simulation program, while versatile and flexible, are modest enough to fit a time shared computer. The PADLOC Q (passive) and AN/SQS-26 CX (active) sonars were taken to characterize the sonar performance envelopes, and the data inputs used for simulation were based on fleet exercises and other measurements where possible. As a result, the gross characteristics, e.g., mean detection range, computed by the simulation correspond well with the limited experience available.
9) Descriptors: Antisubmarine warfare, convoy escort, detection probability, Monte Carlo method, screen, sonar, submarine, surface ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Surface ASW

3) Applicable Situation: Evaluation of escort vessel performance in screening a task force

3.1) Criterion For Success: Detection of submarine

3.2) MOE Selected:

(a) Cumulative probability of one sonar ship detecting the submarine at a specified range from submarine to task force

Rationale For Selection: Using this measure the possible enhancement to classification of simultaneously processed active and passive sonar data (as compared to active only) can be determined.

MOE REVIEW NO. (10)-2

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Electronics Laboratory Center, San Diego, California
2) Report Title: Cost-Effectiveness Comparison of ASW Screen Systems
3) Authors: A.R. Davis and W.T. Rasmussen
4) Report Number: NELC Report 1959 (AD-392 793)
5) Date: 14 May 1968
6) Classification: Confidential
7) Abstract: A determination of the technical feasibility and the operational value of hydrofoils as elements of systems for U.S. Navy missions is presented. In addition, a cost-effectiveness comparison is made for an advanced hydrofoil craft (AHC) and an advanced destroyer escort (ADE) in an ASW screening role in a limited war in the post-1970 era.
8) Descriptors: Antisubmarine warfare, convoy defense, convoy escort, escort ship, personnel, screen, ship defense, sonar, submarine, submarine attack, surface effect vehicle, torpedo

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Surface ASW
3) Applicable Situation: Evaluation of the capability of a surface ship in a screening role
   3.1) MOE's Selected:
      (a) Number of ships required to screen a convoy for a given speed of advance

(b) Hourly operating cost (dollars) to screen a convoy for a given speed of advance

(c) Number of men required to screen a convoy for a given speed of advance

MOE REVIEW NO. (10)-3

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Weapons Center, China Lake, California
2) Report Title: ASW Effectiveness Inside a Screen
3) Authors: D.K. Pack and J.T. Parry
4) Report Number: NWC TP 444 (AD-389 120)
5) Date: February 1968
6) Classification: Secret (NOFORN)
7) Contract: ORD 032 201/200-1/F108-01-01 (Naval Ordnance Systems Command)
8) Abstract: The adequacy of current shipboard ASW weapons is examined against a submarine in the midst of surface ships. Two situations are considered specifically: (1) a submarine within a ship formation attacks and attempts to attack again, and (2) a submarine attempts to remain unharmed under a ship formation. Because torpedoes have not been tested in the vicinity of surface ships, computer simulations of firings of the MK 46 Mod 1 torpedo were used to give an indication of its probable performance in these situations.
9) Descriptors: Antisubmarine warfare, convoy defense, hit probability, Monte Carlo method, screen, ship defense, submarine, surface ship, target acquisition, torpedo

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Surface ASW
3) Applicable Situations:
   3.1) Type: Evaluation of carrier defense capability by a screen unit when a submarine is detected inside a circular screen
      3.1.1) Criterion For Success: Protection of carrier

3.1.2) MOE Selected:

(a) Maximum effective circular-screen radius for weapon placement close to the carrier

3.2) Type: Evaluation of torpedo attack capability

3.2.1) Criterion For Success: Destruction of target

3.2.2) MOE's Selected:

(a) Target acquisition radius

(b) Probability of target acquisition

(c) Probability of hit given acquisition

(d) Time required to hit target

3.3) Type: Evaluation of the effectiveness of an ASW surface force response to a flaming datum

3.3.1) Criterion For Success: Deterrence of submarine from launching its second attack

3.3.2) MOE Selected:

(a) Probability of submarine kill within a specified period of time

MOE REVIEW NO. (10)-4

A. STUDY DESCRIPTION

1) Originatirg Activity: System Analysis Office, ASW Systems Project Office, White Oak, Maryland
2) Report Title: An Investigation of ASW Surface Ship FADAP Data to Estimate Distributions of Classification, Confirmation, Attack and Total Prosecution Time
3) Authors: H.E. Lacey and A.M. Letow
4) Report Number: SAO TM 69-11 (AD-506 254)
5) Date: October 1969
6) Classification: Confidential
7) Abstract: This technical memorandum examines some FADAP data of ASW surface ship initial contacts. The data are analyzed to obtain distributions of classification times, confirmation times, attack times, and prosecution times for valid and false initial contacts. These distributions lead to a number of conclusions regarding the behavior of an ASW system in prosecuting contacts.
8) Descriptors: Antisubmarine warfare, classification, contact investigation, contact prosecution, detection, sonar, submarine, surface ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Surface ASW
3) Applicable Situation: Evaluation of the performance of ASW surface units in prosecuting contacts
   3.1) MOE's Selected:
      (a) Classification time, which is defined as the time between the initial contact and the classification of the initial contact

(b) Confirmation time, which is defined as the time between the initial contact and the gain of the same contact by a sensor of another ASW platform

(c) Attack time, which is defined as the time from initial contact to the launching of a weapon by the ship holding contact

(d) Prosecution time, which is defined as the time from initial contact to the time the contact was broken by the ship holding the initial contact

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: ASW Hold-Contact and Attack Performance
3) Authors: W. B. Buchanan and N. K. Senti
4) Report Number: OEG Study No. 758 (AD-519 401)
5) Date: September 1971
6) Classification: Secret
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: Results of fleet exercises conducted from 1966 through 1970 are analyzed, compared and combined with similar results from 1960 to 1965 to determine the ability of ASW forces to maintain contact on evasive diesel and nuclear submarines.
9) Descriptors: Aircraft, antisubmarine warfare, contact prosecution, destroyer, exponential density function, kill probability, surface ship, submarine, torpedo

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Surface ASW
3) Applicable Situation: Evaluation of the performance of destroyers in submarine engagements
   3.1) MOE's Selected:
      (a) Estimated mean-contact time (EMCT), which is defined as the ratio of total contact time to the number of lost contacts where the total contact time includes all engagements

         Limitations And Assumptions

         (1) This statistic is the maximum likelihood estimate of the mean under the assumption of exponentially distributed contact times.

(2) EMCT's for multiple units are probably biased slightly high. In most engagements involving several ASW units, a single unit initially holds contact on the submarine and is later joined by other ASW units. The more evasive a submarine is, the more likely it is to break contact before additional units can arrive on the scene. The result is that multiple units tend to engage the less evasive submarines, i.e., those on which it is easier to hold contact, and their resulting EMCT's are probably on the high side.

(b) Attack rate, which is defined as the number of attacks in an engagement

(c) Probability of submarine kill per engagement

(11)

SURFACE AAW

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Measures of Effectiveness of Ship-to-Air Missiles
3) Authors: R.C. Coile and W. F. Whitmore
4) Report Number: OEG Study No. 382
5) Date: 4 April 1949
6) Classification: Confidential
7) Abstract: This study examines the basic philosophy of the use of ship-to-air missiles with a view to determining appropriate measures of effectiveness. The measures considered fall into three main groups, namely: the firing policy, the defense level which the system must furnish, and the missile policy for evading and feinting targets. The point of view considered is operational rather than technical.
8) Descriptors: Aircraft, air-to-surface missile, antiaircraft defense, kill probability, lethality, missile, surface-to-air missile, tactics, vulnerability, warhead

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Surface AAW
3) Applicable Situation: Evaluation of the performance of ship-launched missiles in intercepting aircraft
   3.1) MOE's Selected:
      (a) Missile single shot kill probability
      (b) Exchange ratio of missiles expended per bomber destroyed
      (c) Number of missiles required to destroy a target
      (d) Open fire range, which is defined as the range at which the missile must be launched to meet the target at a desired engagement range

MOE REVIEW NO. (11)-2

A. STUDY DESCRIPTION

1) Originating Activity: Bureau of Naval Weapons, Washington D.C.
2) Report Title: Effectiveness of Deceptive Devices in Fleet Anti-Air Warfare
3) Report Number: NAVWEPS Report 8809 (AD-356 289)
4) Date: December 1964
5) Classification: Secret
6) Abstract: This NAVWEPS report assesses the effectiveness of Task Group decoys as devices to augment Fleet Anti-Air Warfare (FAAW) forces. The technique used in the evaluation was to war game FAAW battles, first with and then without the decoys. The differences in the two battles then indicated the effect of decoys.
7) Descriptors: Airborne attack, aircraft, air-to-surface missile, antiair warfare, carrier, countermeasure, Monte Carlo method, surface ship, surface-to-air missile, task force

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force
2) Function: Surface AAW
3) Applicable Situation: Defense of a carrier against an airborne attack using decoys
   3.1) MOE's Selected:
      (a) Number of hits on the carrier achieved by the offense
      (b) Cost to the defense
      (c) Probability that the decoy deceives the offense

(12)

SURFACE ATTACK

MOE REVIEW NO. (12)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Ordnance Station, Indian Head, Maryland
2) Report Title: Operational Effectiveness of the 8-Inch, 55-Subcaliber Fin-Stabilized Gunfighter Projectile
3) Authors: J. L. Duda, J. V. Michaels, M. J. Lindemann, W. M. Burnett, M. I. Goldberg, T. W. Ammons, S. Danowski and C. J. Swenberg
4) Report Number: IHTR 264 (AD-389 632)
5) Date: 15 March 1968
6) Classification: Confidential
7) Abstract: This report examines the operational effectiveness of the Gunfighter 8-inch, 55-subcaliber fin-stabilized projectile in a North Vietnamese scenario. The Gunfighter concept is capable of doubling or tripling the range of guns by reducing the weight of the projectile, by configuring the projectile for minimum drag, and by improving the propellant. The study includes a dispersion analysis, fire-control problems, availability, round requirements, and cost estimates. The system was found to be effective in terms of the level of effort required for the mission objectives specified.
8) Descriptors: Cost effectiveness, fire control, projectile, surface attack, surface ship, target mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Surface Attack
3) Applicable Situation: Evaluation of the operational effectiveness of projectiles
   3.1) Criterion For Success: Destruction of target
   3.2) MOE's Selected:
      (a) Cost effectiveness, which is defined as the ratio of

attendant cost to system effectiveness. System effectiveness is the probability that a system can successfully meet its operational demands throughout a given time period when operated in a specific environment.

(b) Number of rounds required for the completion of a particular mission

MOE REVIEW NO. (12)-2

A. STUDY DESCRIPTION

1) Originating Activity: U. S. Naval Weapons Laboratory, Dahlgren, Virginia
2) Report Title: Effectiveness of 5"/54 Mark 42 and Mark 45 and 175mm Gun Suites Against a Moving Target Using Non-Adaptive Linear Prediction
3) Author: D. F. Eliezer
4) Report Number: NWL-TM-K-32/67 (AD-506 312)
5) Date: June 1967
6) Classification: Confidential
7) Abstract: As part of the design stage of the ship acquisition process for the DX/DXG (destroyer type ship) it was desired to compare the effectiveness of various gun suites which could be carried by the ship against a high speed, highly maneuverable surface target. A computerized model was implemented to permit this to be done. This report gives the results obtained from this model which indicate the effectiveness of various gun suites composed of 5"/54 and 175mm guns against a moving target.
8) Descriptors: Destroyer, gun, kill probability, Monte Carlo method, projectile, surface attack, surface target

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Surface Attack
3) Applicable Situation: Evaluation of the performance of gun suites against a moving surface target
   3.1) Criterion For Success: Abortion of an attack by the target

3.2) MOE's Selected:

(a) Cumulative kill probability for a specified range

Limitations And Assumptions:

(1) Since the objectives of the guns are assumed to be self protection, anything which would abort an attack by the target is considered a kill.

(b) Number of rounds and range necessary for a specified percent kill

MOE REVIEW NO. (12)-3

A. STUDY DESCRIPTION

1) Originating Activity: Office of the Chief of Naval Operations, Washington, D.C.
2) Report Title: The Utility of Shore Bombardment Missiles for Amphibious Support
3) Report Number: NAVWAG Study No. 14
4) Date: 2 November 1960
5) Classification: Secret
6) Abstract: Shore bombardment missiles, aircraft and naval gunfire are compared for use in a variety of typical amphibious support missions. The shore bombardment missiles are assumed to have various types of terminal and inertial guidance, and controlled fragmentation or high explosive warheads. Some effects of missile reliability and aircraft attrition are considered in the analysis. The relative efficiency of the weapons is expressed in terms of ship capacity required and logistic cost for specified mission effectiveness.
7) Descriptors: Air-to-surface missile, amphibious operation, carrier, carrier based aircraft, logistics, surface attack, surface ship, surface-to-surface missile, target mix, task force

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Surface Attack
3) Applicable Situation: Evaluation of the use of shore bombardment missiles in an amphibious operation
   3.1) MOE's Selected:
      (a) Fraction of ship capacity which must be expended to achieve an 80% probability of damaging a target (or, in the case of troop targets, the fraction of capacity to achieve 30% expected damage)

Rationale For Selection: Ship capacity was chosen as the measure of effectiveness instead of dollar cost since only a small number of shore bombardment missiles can be carried in the missile magazines of ship designs considered in this study. This number is so small that it will be the most immediate and inescapable limitation in the operational capabilities of a ship or task force equipped with shore bombardment missiles. This limitation is probably as relevant as the dollar cost of shore bombardment missiles; operationally, it is clearly much more important.

(b) Logistic cost in cubic feet to achieve an 80 percent probability of damage (or 30 percent expected coverage for troop targets)

Rationale For Selection: Logistic cost was selected in preference to financial cost. It is not clear that shore bombardment missiles, naval guns, and carrier aircraft compete meaningfully for budget support. Aircraft and CVA force levels will be determined independently of any possible offsetting shore bombardment capability if only because aircraft have important capabilities not possessed by shore bombardment missiles. In addition, aircraft, shore bombardment missiles and guns have radically different capabilities, which makes a useful cost comparison almost impossible. Further unrealism would be introduced in computing the costs of aircraft attrition and in attempting to determine actual out-of-pocket costs (as opposed to total system costs) which are relevant to future budgets. Finally even if these problems could be resolved, there is the problem of comparing the fairly well known costs of aircraft and their armament with preliminary and optimistic estimates of missile costs. In the case of logistic

costs, all systems compete on commensurable terms. Volume is more easily and reliably predictable than dollar cost and is an appropriate measure frequently used in the shipping industry.

(13)

SEA BASED STRATEGIC SYSTEMS

MOE REVIEW NO. (13)-1

A. STUDY DESCRIPTION

1) Originating Activity: General Research Corporation, Arlington, Virginia
2) Report Title: ULMS Effectiveness Studies: Missiles Per Submarine
3) Authors: P. E. Scesney, E. J. Ortlieb and W. R. Thomson
4) Report Number: CR-3-142 (AD-516 268)
5) Date: July 1971
6) Classification: Secret
7) Contract: N00014-69-C-0295 (Office of Naval Research)
8) Abstract: Factors involved in choosing the number of missiles to be carried by each ULMS submarine are examined in terms of the trade-off between system cost and system effectiveness. To display variations due to missiles per submarine, several measures of survivability. cost and cost effectiveness are used. The effects of other variables are parameterized over the ranges of interest.
9) Descriptors: Antimissile missile, antisubmarine warfare, barrier, cost, cost effectiveness, kill probability, radar, sea based strategic system, sea launched missile, sonar

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Sea Based Strategic Systems
3) Applicable Situation: Evaluation of an undersea long-range missile system
   3.1) MOE's Selected:
      (a) Survivable throw weight per unit cost
      (b) Number of missiles maintained on-station per billion dollars of system cost

      Limitations And Assumptions:

      (1) This measure is strongly dependent on the details of the scenario as well as those of the cost analysis.

(2) The exact level of cost depends on many factors and, furthermore, the cost figures face modification due to inflation, more design information, and better component estimates.

(c) Cost exchange ratio required for blunting, which is defined as the ratio of enemy cost to blunt a system to the U.S. cost to develop and deploy it

Limitations And Assumptions:

(1) Accurate determination of this cost exchange ratio requires detailed studies of the enemy systems as well as the problem at hand. It also requires knowledge of enemy reaction cost for different scenarios.

(14)

ELECTRONIC WARFARE

MOE REVIEW NO. (14)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center For Naval Analyses, Arlington, Virginia
2) Report Title: Potential Effects of Defensive Electronic Countermeasures in Fleet Anti-Air Warfare
3) Author: A.M. Salzberg
4) Report Number: NAVWAG Research Contribution No. 79 (AD-392 868)
5) Date: February 1968
6) Classification: Secret
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: Possible countermeasures are discussed for an anti-ship missile with active radar guidance. A computer program is given which simulates interactions of such a missile with ships, track-breakers, and decoys. Computer results are given which show the effects of variation of such factors as missile velocity and track-breaker reliability.
9) Descriptors: Aircraft, air-to-surface missile, antiair warfare, countermeasure, decoy, detection, electronic warfare, missile, missile seeker, radar, ship defense, surface-to-surface missile

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Electronic Warfare
3) Applicable Situation: Evaluation of the duel between an incoming missile and ship-based defensive ECM
   3.1) MOE Selected: Probability that the missile is locked on the ship at end of flight
   Rationale For Selection: This is a measure of the potential effects of defensive ECM on the chances of a missile successfully homing on a ship.

MOE REVIEW NO. (14)-2

A. STUDY DESCRIPTION

1) Originating Activity: Naval Air Test Center, U.S. Naval Air Station, Patuxent River, Maryland
2) Report Title: Evaluation of the AN/ALT-35, Final Report
3) Authors: T.M. Maroldy and J.R. Seale
4) Report Number: WST-002R-72 (AD-519 831)
5) Date: 16 March 1972
6) Classification: Secret
7) Abstract: Results of laboratory and flight tests are presented for the AN/ALT-35 electronic countermeasures system to determine conformance to specifications and suitability for mission use.
8) Descriptors: Aircraft, countermeasure, detection, electronic warfare, radar

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Electronic Warfare
3) Applicable Situation: Evaluation of jammer performance against radars
   3.1) Criterion For Success: Reduction of aircraft susceptibility to detection
   3.2) MOE's Selected:
      (a) Blip-scan ratio, which is defined as the number of times that a particular target is observed to the number of times it could have been observed

         Rationale For Selection: The blip-scan ratio can be considered as the probability of detection upon a single enemy radar scan, with no knowledge assumed for the previous scan.

(b) Burnthrough range

Rationale For Selection: The burnthrough range is a measure of the detection range of the jammer-equipped aircraft.

(15)

UNDERSEA SURVEILLANCE

MOE REVIEW NO. (15)-1

A. STUDY DESCRIPTION

1) Originating Activity: Cornell Aeronautical Laboratory, Inc., Buffalo, New York.
2) Report Title: Acoustic Countermeasures Study - Tactical Techniques to Improve ASW Early Warning in Task Force Operations
3) Authors: B. B. Levitt and M. W. Zumwalt
4) Report Number: GM-2268-G-3 (AD-502 608)
5) Date: 31 December 1968
6) Classification: Secret (NOFORN)
7) Contract: N00014-66-C-0232 (Office of Naval Research)
8) Abstract: This study concerns itself with an examination of the means of increasing the geographic area in which SOSUS alerts may be expected. A procedure was developed to assess the SOSUS early warning assistance available to a task force (or to any ship or group of ships) proceeding along an established track. As a result, a methodology was developed to provide a means for evaluating alternate carrier task force track patterns to determine which one provides the maximum degree of early warning assistance from the SOSUS network.
9) Descriptors: Antisubmarine warfare, detection, Monte Carlo method, SOSUS, submarine, task force, undersea surveillance

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Undersea Surveillance
3) Applicable Situation: Evaluation of the effects of variations in carrier task force track patterns on SOSUS early warning assistance

3.1) Criterion For Success: Reduction of the sleeve of no SOSUS coverage about a proposed carrier task force track

3.2) MOE Selected:

(a) SOSUS no-detection area, which is defined as the geographic area adjacent to the carrier task force track in which SOSUS cross-fix capability is below a selected probability level

Rationale For Selection: This measure can provide the basis for comparing various carrier task force track patterns and, as a result, lead to the selection of a track which would provide maximum SOSUS assistance.

MOE REVIEW NO. (15)-2

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Air Development Center, Johnsville, Pennsylvania
2) Report Title: Classified
3) Author: E. P. Garabed
4) Report Number: NADC-AE-6939 (AD-508 543)
5) Date: 16 April 1970
6) Classification: Secret
7) Project Number: AIRTASK A37533/202/69F08-121-702 Work Unit No. 2 (Naval Air Systems Command)
8) Abstract: This study determines the theoretical optimum Difar hydrophone depth in a specified body of water using a computer model.
9) Descriptors: Antisubmarine warfare, detection, Difar, sonobuoy, submarine, undersea surveillance

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Undersea Surveillance
3) Applicable Situation: Evaluation of sonobuoy detection capability
   3.1) Criterion For Success: Detection of submarine
   3.2) MOE Selected:
      (a) Average detection range achieved for a specified sonobuoy depth

(16)

AMPHIBIOUS ASSAULT

MOE REVIEW NO. (16)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Naval Gunfire Support Vols I-III
3) Author: A. L. Karp
4) Report Number: NWAG Study No. 36 Vols I-III (AD-502 441, AD-502 442 and AD-502 443)
5) Date: 25 February 1965
6) Classification: Secret (NOFORN)
7) Contract: NONR 3732(00) (Office of the Chief of Naval Operations, Systems Analysis Division)
8) Abstract: In order to provide information necessary for selecting adequate levels and composition of naval gunfire support forces, the effectiveness and costs of alternative fire support forces are examined in the context of amphibious assaults of Marine Expeditionary Force size.
9) Descriptors: Amphibious operation, cost, gun, Monte Carlo method, naval gunfire support, surface ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Amphibious Assault
3) Applicable Situations:
   3.1) Type: Evaluation of a single tube of a gun battery or a single round
      3.1.1) MOE's Selected:
         (a) Accuracy of the gun
         (b) Range of the gun
         (c) Firing rate of the gun
         (d) Expected number of rounds required to

achieve some specified damage or casualty level on a particular type of target

Rationale For Selection: While those measures of effectiveness are all of importance, they are seldom explicitly called out. Instead, they are combined into measures of effectiveness at a higher level.

3.2) Type: Evaluation of the gunfire support for a given ship class

3.2.1) MOE's Selected:

(a) Amount of time a battery must fire to achieve specified damage or casualty levels against a representative spectrum of targets at various ranges

(b) Percentage of a ship's ammunition of a given type that must be expended in order to accomplish the desired results against representative targets at various ranges

3.3) Type: Evaluation of total fire support forces

3.3.1) MOE's Selected:

(a) Live target time, defined as the time interval from the occurrence of a target until some weapon system has fired the expected number of rounds required to achieve the required effects upon the target

Limitations And Assumptions:

(1) Live target time is summed over all of the targets that occur.

(b) Target firing time, defined as the time interval measured to the impact of the first fire-for-effect volley or salvo

Rationale For Selection: The logic underlying the terminology is that a piece will continue firing even when individual

spotting rounds are being fired, but when the fire-for-effect salvos begin to impact, the crew will no longer fire the weapon in an effective manner.

Limitations And Assumptions:

(1) In some cases, spotting fire may suppress the use of the pieces; in other cases, the piece may continue the mission until fire-for-effect achieves a sufficient level of casualties. However, it is reasonable to assume that suppression begins with the arrival of the first fire-for-effect rounds.

(c) Number of lost targets, defined as the number of targets which have occurred within the fire support system but which disappear before fire-for-effect commences, either because they displace and are lost to the observer or because they close with (or are closed by) landing force units and can no longer be attacked by the fire support system

Rationale For Selection: Lost targets are more important than they might at first seem. First, if they and the landing force close, higher casualties may be expected than in the situation in which they are disposed of by the first support system. Second, targets that disappear because of displacement can be expected to reoccur.

(d) Maximum length of the target queue, defined as the largest number of targets, for which, at any one time, call-fire missions had been requested but not completed

(e) Amount of ammunition available to the force for other than call-fire missions

(17)

NAVAL COMMUNICATIONS

MOE REVIEW NO. (17)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Electronics Laboratory Center, San Diego, California
2) Report Title: Navy Shipboard Communications Technical Control Systems Analysis - Part I: Functional Analysis and Systems Synthesis, and Part II: Mathematical Modeling and Final Results
3) Authors: C.L. Slager (Part I) and L.M. Hamerman (Parts I & II)
4) Report Number: TM-1083 (Part I) and TN-1360 (Part II)
5) Date: 20 March 1967 (Part I) and 12 February 1968 (Part II)
6) Classification: Unclassified (Part I) and confidential (Part II)
7) Abstract: This study relates measures of technical control performance to factors which can be controlled in system design. The alternative design approaches emphasize key system variables such as the time sharing of communications facilities, complexity of control required, levels of fault isolation and replacement of circuit failure sources, and degree of automation. Part I of this study develops the alternative communications technical control approaches to be evaluated and compared, and an analysis methodology. Part II presents system mathematical models, sensitivity analyses, criteria evaluations and costs for each of the alternatives.
8) Descriptors: Circuit performance, communication, message traffic

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Naval Communications
3) Applicable Situation: Assessment of the performance and support requirements of a communications subsystem supporting a weapons platform

3.1) MOE's Selected:

(a) Circuit usage

Rationale For Selection: This is a measure of the distribution of available circuit time among productive usage, nonproductive usage and nonuse (idle time). Productive usage is defined as that percentage of time spent in the actual transmission of intelligence or information. Nonproductive usage refers to that percentage of transmission time spent on coordination and administrative traffic related to circuit control. Idle time refers to that percentage of circuit time which would be, on the average, unused.

(b) Number of circuits required

Rationale For Selection: This can be used as a measure of the cost of system design and depends upon both the anticipated traffic load and the system characteristics.

(c) Number of equipments required

Rationale For Selection: This measure reflects not only the amount of circuit componentry required, but also the associated equipment for the control and support activity.

(d) Number of personnel required

Rationale For Selection: This is a measure of operating personnel and direct support personnel needs

(e) Total system lifetime cost

(f) Size

(g) Weight

(h) Power requirement

(i) Reliability of circuit performance

Rationale For Selection: This is a measure of the circuit's invulnerability to outages caused

by equipment, personnel or medium/environment problems.

(j) System confidence level, defined as the probability that a specified number of a totality of circuits is available at any time

Rationale For Selection: System confidence level can be applied to reflect pure circuit availability as a function of circuit reliability and maintainability. In addition, it can reflect the combined effects of operational availability and circuit usage, thus providing a measure of the probability of delay in obtaining access to the circuit.

(k) Flexibility

Rationale For Selection: This is a measure of the inherent rigidity of the design and relates to the ability to adapt in a meaningful and timely way to unforseen situations.

(l) Jamming vulnerability

(m) Vulnerability to enemy detection

(n) Growth potential

Rationale For Selection: This is a measure of the ease with which hardware and personnel can be added in order to increase capacity, and relates to the possibility of increasing system capacity without system reorganization.

(o) Efficiency of spectrum use

Rationale For Selection: This is a measure of the ability to pass the most traffic using the least amount of spectrum.

(p) Ease of installation

Rationale For Selection: This relate[illegible] e total number of equipments required for a [illegible] ıpacity, their size, modularity, relative po[illegible] nd power requirements, the number of i[illegible] ıctions,

etc., and the ease of installing these on the appropriate platform.

(q) Survivability

Rationale For Selection: This is directly related to the degree of dependence on centralized operations, such as relay points and centralized control.

(r) Ease of implementation

Rationale For Selection: This measure is concerned with the feasibility of developing and utilizing communication system concepts. It accounts for the complexity requirement for new development and the degree to which success depends upon improvements in state-of-the-art.

(s) Maximum confidence level for flash traffic, defined as the probability that each flash message is serviced within the time threshold specified for that precedence

MOE REVIEW NO. (17)-2

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Utility of Satellite Communications in Naval Operations
3) Authors: J.C. Aller, G.W. Burch, M.J. Greene and E. Kapos
4) Report Number: OEG Study No. 698 (AD-375 202)
5) Date: 14 July 1966
6) Classification: Secret
7) Contract: NONR 3732(00) (Office of Naval Research)
8) Abstract: The expected utility of satellite communications in naval operations is analyzed in the light of teletype message flow and tactical communications in several crisis control and limited war operations, and fleet exercises. The utility of satellite communications in general war is also considered.
9) Descriptors: Communication, message traffic, satellite

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Naval Communications
3) Applicable Situations:
   3.1) Type: Evaluation of the traffic volume capabilities of a communication system
      3.1.1) MOE's Selected:
         (a) Average data rate (in words per minute)
         (b) Peak data rate (in words per minute)
         (c) Average daily traffic load
   3.2) Type: Evaluation of a communication system's performance
      3.2.1) MOE's Selected:
         (a) Median message delay time
         (b) Percent of messages meeting specified delay standard

3.3) Type: Evaluation of a communications system location security

3.3.1) MOE Selected:

(a) Detectability of transmissions

3.4) Type: Evaluation of a communications security from jamming

3.4.1) MOE Selected:

(a) Ratio of jammer power to signal power

MOE REVIEW NO. (17)-3

A. STUDY DESCRIPTION

1) Originating Activity: IIT Research Institute, Chicago, Illinois
2) Report Title: Study of Concepts for Navy Tactical Voice Communications
3) Authors: R.V. Janc, B.I. Marks and N.T. Thomopoulos
4) Report Number: Technical Report 11
5) Date: April 1972
6) Classification: Unclassified
7) Contract: N00014-70-C-0375 (Office of Naval Research)
8) Abstract: The objective of the effort discussed in this report was to formulate and develop an analytical model based on queueing theory for the purpose of evaluating various tactical voice net configurations and signaling alternatives. Results presented from the analytic queueing model are presented here in the context of specific Naval tactical net situations. The results illustrate only the use of the methodology developed; consequently, mathematical derivations have been omitted with the exception of a brief technical summary. Specifically, those areas examined are mutual signaling interference, multiple access-discrete address (MADA) systems, preemptive/non-preemptive priority, busy signal, hold call and non-Poisson statistics. For each of these, various performance measures are illustrated graphically as functions of net utilization.
9) Descriptors: Communications, data link, exponential density function, Markov process, message traffic, Poisson density function, queueing

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Naval Communications

3) Applicable Situations:

3.1) Type: Evaluation of the capability of a radio operator to transmit and receive messages in a voice radio network

3.1.1) MOE's Selected:

(a) Grade of service, defined as the probability an operator will encounter a delay given he wishes to send a message

(b) Mean access delay, defined as the average time for an operator to get on the air given he has encountered a delay

3.2) Type: Evaluation of the efficiency of message transfer within a communication net

3.2.1) MOE's Selected:

(a) Average number of messages in the net queue

(b) Mean waiting time in the net queue

MOE REVIEW NO. (17)-4

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Electronics Laboratory Center, San Diego, California
2) Report Title: Analysis of Amphibious Communications Requirements for the Assault Phase, Ship-to-Shore Movement
3) Authors: B.B. Briant, A.W. Harris, T.W. Runk and E.J. Hauber
4) Report Number: NELC 1648 (AD-519 678)
5) Date: 6 October 1969
6) Classification: Confidential
7) Project Number: S32-63, Task 10192 (NELC B601) (Naval Ship Systems Command)
8) Abstract: Communications requirements in the ship-to-shore movement of an assault phase of an amphibious operation are predicted in this report. The equipment needed for each system platform and the relative optimality of a system were also determined. Use of the tables developed in this report will permit better communications with fewer channels.
9) Descriptors: Aircraft, amphibious operation, circuit performance, command and control, communications, data link, helicopter, message traffic, surface ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Naval Communications
3) Applicable Situation: Evaluation of communications system performance
   3.1) MOE Selected:
      (a) Average message delay time as a function of usage level

(18)

COMMAND AND CONTROL

MOE REVIEW NO. (18)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Electronics Laboratory Center, San Diego, California
2) Report Title: ASW Ship Command and Control: The Expected Increase in ASW Force Effectiveness
3) Report Authors: C. H. Sturtevant and L. A. Harvey
4) Report Number: TM-1117
5) Date: 2 June 1967
6) Classification: Confidential
7) Abstract: This memorandum reports the results of a preliminary application of system and operations analysis techniques to indicate the increase in an ASW force's performance at the tactical level that can be expected when one or more ASW Tactical Data System equipped ships are included in the force complement. The study is a broad overview of a number of missions and tactical encounter situations in which emphasis was placed on those command and control parameters which exert a major influence on ASW system effectiveness. Conventional ASW Command and Control (CIC) and ASW Ship Command and Control System (C&CS) performances are compared for each tactical situation examined.
8) Descriptors: Antisubmarine warfare, combat information center, command and control

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Command and Control
3) Applicable Situation: Evaluation of the relative performance between two command and control system alternatives

3.1) MOE's Selected:

(a) Command and control relative effectiveness, defined to be the difference between the corresponding average probabilities of ASW mission success divided by the average probability of ASW mission success of a specified alternative

(b) Average probability of ASW mission success, defined to be the weighted sum of the probability of mission success when a specified ASW role is examined within a given mission type, where the weighting factors are for each mission type and role within a mission

Rationale For Selection: Measures of effectiveness for a command and control function are exceedingly difficult to specify. An ASW command and control system depends upon many interrelated factors involving, in addition to sensor and weapon systems, the navigation system, the communication system, ship control system, and the interface between the command and control team and the equipment. The wide variation in the various ASW tasks the ASW ship must perform adds still another dimension to the complexity of command and control.

(20)

RECONNAISSANCE/INTELLIGENCE

MOE REVIEW NO. (20)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Air Development Center, Johnsville, Pennsylvania
2) Report Title: Cost-Effectiveness Analysis of Alternative Configurations of an AIRS (Airborne Integrated Reconnaissance System), Vol. 1 Concepts and Math Model Descriptions and Vol. 2 Configuration Descriptions and Cost-Effectiveness Results
3) Author: A. C. Knobloch
4) Report Number: NADC-SD-7015 (AD-513 647 and AD-513 641)
5) Date: 25 May 1970 (Vol. 1) and 30 June 1970 (Vol. 2)
6) Classification: Secret
7) Project Number: Airtask A05-510-220/202-1/W36-40-000 (Naval Air Systems Command (AIR-510))
8) Abstract: Volume 1 of this report describes a series of mathematical models that have been constructed to determine the cost effectiveness of tactical airborne reconnaissance systems. The data required by the models, the information generated within them, and the interfaces between the various models are described in detail. Also discussed are a number of tactical reconnaissance concepts that these models are intended to evaluate. In Volume 2, three reconnaissance scenarios are described, and six alternate sensor configurations are presented. The results of a simulation of the performance of these alternate configurations are presented, and the cost-effectiveness analysis and results are described.
9) Descriptors: Aircraft, amphibious operation, biological sensor, carrier based aircraft, chemical sensor, cost, cost-effectiveness, countermeasure, detection probability, electronic warfare, infrared sensor, intelligence, localization probability, optical sensor, photo interpretation, radar, reconnaissance, radiological contamination sensor

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Reconnaissance/Intelligence
3) Applicable Situations:
   3.1) Type: Evaluation of reconnaissance system performance in identifying and localizing targets
      3.1.1) Criterion For Success: Successful collection of target identification and position information
      3.1.2) MOE's Selected:
         (a) Average probability that the system or sensor is capable of detecting targets of interest
         (b) Average probability that the system or sensor is capable of both detecting and correctly identifying targets of interest
         (c) System or sensor's ability to localize targets once the targets have been identified
         (d) System or sensor's time late, which is defined as the time between detection by the system or sensor and the first availability of this information for operational use
   3.2) Type: Evaluation of the contribution of reconnaissance system performance to strike aircraft penetration of a SAM barrier
      3.2.1) Criterion For Success: Survival of penetrating strike aircraft
      3.2.2) MOE's Selected:
         (a) Total attrition due to SAM's that is prevented by the information provided by the reconnaissance sortie
         (b) Total attrition due to hostile interceptors that is prevented by information provided by the reconnaissance sortie

3.3) Type: Evaluation of the value of reconnaissance information for the interdiction mission in which strikes are made at enemy truck traffic

3.3.1) Criterion For Success: Destruction of trucks

3.3.2) MOE Selected:

(a) Expected number of trucks destroyed per convoy as a function of reconnaissance system localization accuracy

3.4) Type: Evaluation of the influence and effect of reconnaissance system performance on sortie requirements

3.4.1) MOE's Selected:

(a) Number of reconnaissance sorties needed to support an operational situation

(b) Probability that operationally useful information about a particular target is on hand

Rationale For Selection: This is a measure of information quality, not a descriptor of the contents of the data package, but indicates the probability that the data package is indeed available. Quality of information concerning a particular target is defined by specifying a minimum acceptable probability of detection (for moving targets) or identification (for stationary targets).

(c) Number (or percentage) of targets about which quality information is delivered by surveillance

Rationale For Selection: This is a measure of information quantity.

(d) Fraction of operational time in which "live" information of acceptable quality and quantity is in hand

Rationale For Selection: This is a measure of fractional time coverage. By "live" data is meant those data products which are sufficiently current to be operationally useful.

(e) Number of reconnaissance sorties needed to deliver "live" or operationally useful information

(f) Fraction of targets for which the detectability/identifiability is greater than a given value as a function of revisit time

(g) Total number of attack sorties saved as a function of the time delay between the gathering of and the using of information from a reconnaissance sortie

(h) Reduction in the strike effort (required to perform a specific task) which is made possible by the use of information gathered by reconnaissance

(i) Number of strike sorties not wasted

3.5) Type: Determination of the impact on operational costs due to reconnaissance system performance

3.5.1) MOE's Selected:

(a) Life cycle cost per flight hour of the reconnaissance system and its associated equipments

(b) Cost of attack sorties that are not wasted

(c) Strike costs saved as a function of reconnaissance sortie cost

3.6) Type: Evaluation of photo interpretation performance

3.6.1) MOE's Selected:

(a) Rate at which target data can be evaluated using imagery provided by a reconnaissance system

(b) Time required to extract intelligence data from imagery

(c) Probability of keying on a given frame

(d) Number of target images analyzed per manhour of effort

<u>Rationale For Selection</u>: This is a measure of photo interpreter efficiency.

(e) Fraction of available target images which have been evaluated as a function of the average delay time, where delay time is defined as the time interval between the gathering of the raw data and the availability of the evaluated information

3.7) Type: Evaluation of radar detection capability

3.7.1) Criterion For Success: Detection of target

3.7.2) MOE Selected:

(a) Probability that the signal exceeds a threshold which has been set to keep the false alarm rate at some suitable level

MOE REVIEW NO. (20)-2

A. STUDY DESCRIPTION

1) Originating Activity: Stanford Research Institute, Menlo Park, California
2) Report Title: A Classification System, Measures of Effectiveness, and Model for Countersurveillance
3) Author: J.R. Payne
4) Report Number: SRI-71-1783 (AD-518 253)
5) Date: September 1971
6) Classification: Confidential
7) Contract: DACA 76-69-C-0003 (U.S. Army Engineer, Topographic Laboratories)
8) Abstract: This report summarizes: (1) the formulation of a classification system for environments, military situations, target elements, targets, and target complexes that should be useful in the development of countersurveillance measures when the results of countersurveillance experiments and studies are arranged in the manner specified; (2) the identification of measures of effectiveness for countersurveillance systems at three levels of interest: (a) analysis of the use of countersurveillance by a military force, (b) analysis of countersurveillance operations, and (c) design and use of specified materiel, techniques, or doctrine; (3) a description of SCREEN, a model for simulating the operational use of surveillance and countersurveillance systems; and (4) the development of field test procedures that can be used to evaluate SCREEN and countersurveillance techniques.
9) Descriptors: Classification, countermeasure, decoy, detection probability, false target, intelligence, reconnaissance, surveillance

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Reconnaissance/Intelligence

3) Applicable Situations:

3.1) Type: Evaluation of the success in using countersurveillance techniques in military operations in specific situations and environments

3.1.1) Criterion For Success: Reduction in enemy surveillance capability of friendly forces

3.1.2) MOE's Selected:

(a) Probability of detection
(b) Probability of recognition
(c) Probability of identification
(d) Timeliness of surveillance data generated
(e) Area coverage
(f) Range of detection
(g) Time of search before location
(h) Number of targets detected
(i) Percentage of targets located
(j) Accuracy of intelligence data in terms of targets correctly identified, false alarms, targets missed and targets incorrectly located

3.2) Type: Evaluation of techniques for applying countersurveillance material to the objects to be protected and procedures for using and maintaining countersurveillance materiel

3.2.1) Criterion For Success: Reduction in enemy surveillance capability of friendly forces

3.2.2) MOE's Selected:

(a) Ratio of the reflectance of the material to the reflectance of the background (contrast) as a function of wave-length
(b) Emissivity of the material and background
(c) Correlation between the apparent pattern and the pattern of the background
(d) Signal-to-noise ratio
(e) False-alarm rate
(f) Time to set up

(1, 10)

AIRBORNE ASW AND SURFACE ASW

MOE REVIEW NO. (1,10)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Performance of Search Attack Units in Fleet Exercises 1961-1965
3) Author: W. B. Buchanan
4) Report Number: OEG Study No. 717 (AD-392 674)
5) Date: 19 August 1968
6) Classification: Confidential
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: This study compiles data on the performance of search attack units (SAU) in Fleet exercises from 1961 through 1965. For situations in which detection occurred, data on the sequence of events as well as the detection and attack phases of the SAU - submarine engagement are given. Also discussed are the effects of submarine intent, number of destroyers, the presence of aircraft, and type of submarine on the performance of the SAU. The study explores a number of measures of effectiveness which may guide those querying the growing FADAP (Fleet ASW Data Program) data bank. This analysis does not include a study of the search effectiveness of SAU's, and is confined to situations in which engagement, detection of the submarine by ASW forces or detection of the ASW forces by the submarine, occurred.
9) Descriptors: Aircraft, destroyer, detection, FADAP, kill probability, search, sonar, submarine, surface ship

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne ASW and Surface ASW

3) Applicable Situation: Evaluation of the detection and attack phase of the search attack unit - submarine engagement

3.1) Criterion For Success: Detection and destruction of submarine

3.2) MOE Selected:

(a) Units attacked ratio, defined as the ratio of the number of submarines attacked at least once to the number of destroyers attacked at least once

Rationale For Selection: There are basically two forms of the units attacked ratio, namely, the definite ratio and the combined attack ratio. The former considers only those units definitely attacked, where definite attacks are defined to be those made by units which have not themselves been attacked and thus are surely able to attack. The latter considers all units which were attacked, either definitely or possibly. The definite units attacked ratio shows considerably more variability than the combined units attacked ratio, and gives perhaps the better insight into the action as it reflects which units attacked before they themselves were taken under attack.

Limitations And Assumptions:

(1) An engagement was reported if the submarine approached the destroyer to within the data collection range of active sonar, or if an attack was made.

(2) The intent of the submarine during the initial stages of the engagement was not normally given explicitly in the reports, and therefore had to be inferred from the context of the situation and the overt actions of the submarine.

(3) The definite units attacked ratio, if interpreted as an exchange ratio, assumes a kill probability of unity per attack.

(4) The units attacked ratios do not reflect multiple attacks on the same unit, specifically, during an engagement a submarine may suffer several definite attacks, but this is counted as only one submarine definitely attacked in the units attacked ratio. Since the ASW forces normally make more attacks per engagement than the submarine, the ratios tend to be biased in favor of the submarine if interpreted as exchange ratios.

MOE REVIEW NO. (1,10)-2

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: The False Attack Question in ASW
3) Authors: W. B. Buchanan and E. D. Freilich
4) Report Number: OEG Research Contribution 191 (AD-516 804)
5) Date: June 1971
6) Classification: Secret
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: The two measures used to estimate the number of torpedoes expended on false attacks in antisubmarine warfare, the false attack ratio and the false attack rate, are compared. Although neither method is completely satisfactory, the false attack ratio is found preferable to the false attack rate for estimating future torpedo requirements.
9) Descriptors: Aircraft, antisubmarine warfare, false target, submarine, surface ship, torpedo

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne ASW and Surface ASW
3) Applicable Situation: Evaluation of false attack frequency and rate of occurrence in ASW
   3.1) MOE's Selected:
      (a) False attack ratio, which is defined as the ratio of false attacks to valid attacks

         Rationale For Selection: This measure has been demonstrated to be quite stable over many types of operations, is easy to apply and does not require in its formulation/use any estimate of on-station time or the duration of the war.

Limitations And Assumptions:

(1) It does not explicitly account for the amount of ASW search against enemy submarines (although it can be argued that since the number of valid attacks also depends on the ASW effort, this factor is implicitly included in the ratio).

(2) It cannot be used to predict false attacks in limited geographical areas.

(3) This measure requires a reasonably accurate estimate of the weapon kill probability if a ratio based on re-attack data is used (since with this method, false re-attacks depend on valid re-attacks, which in turn depend on the weapon kill probability).

(b) False attack rate, which is defined as the number of false attacks per 100 hours

Rationale For Selection: This measure accounts explicitly for the ASW effort. It predicts false attacks in areas where no valid attacks have occurred and thus corresponds to experience.

Limitations And Assumptions:

(1) It does not explicitly depend on the rate of valid attacks, which is contrary to experience.

(2) It varies widely over different operations and is therefore difficult to predict.

(3) This measure is more difficult to apply, as the duration of the war must be specified as well as the on-station times of the units involved.

(2, 3)

AIRBORNE AAW AND AIRBORNE ATTACK

MOE REVIEW NO. (2,3)-1

A. STUDY DESCRIPTION

1) Originating Activity: Stanford Research Institute, Menlo Park, California
2) Report Title: Assessment Models and Methodologies of the Value of Tactical Early Warning and Surveillance in Naval Warfare
3) Author: P.A. Banks
4) Report Number: NWRC-RM-47 (AD-844 140)
5) Date: May 1968
6) Classification: Unclassified
7) Contract: N00014-68-A-0243 (Office of Naval Research)
8) Abstract: The study of military weapons systems is pursued under many names: operations research, operations analysis, systems engineering, systems research, and systems analysis. This paper presents a conceptual formulation for the coordination of these efforts to assess the effectiveness and worth of systems. It is presented in the context of a particular Naval problem and is written for staff level personnel within the Department of Defense.
9) Descriptors: Airborne attack, aircraft, air superiority, availability, countermeasure, detection, kill, radar, reliability, surface-to-air missile, surveillance, survivability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne AAW and Airborne Attack
3) Applicable Situations:

   3.1) Type: Evaluation of aircraft performance in an air superiority mission

3.1.1) MOE's Selected:

(a) Enemy aircraft destroyed

(b) Enemy airfields out of commission

(c) Friendly strikes unengaged

(d) Enemy SAM's launched

(e) Enemy SAM sites destroyed

(f) Friendly aircraft destroyed

(g) Enemy aircraft encountered

(h) Friendly strikes engaged

(i) Friendly air superiority weapons launched

(j) Enemy weapons penetrators

(k) Friendly forces committed to air superiority roles

Rationale For Selection: MOE's (a)-(e) are measures of the military cost to the enemy and MOE's (f)-(k) are measures of the military cost to the friendly forces.

3.2) Type: Evaluation of the performance of an early warning or surveillance system

3.2.1) MOE's Selected:

(a) Probability of detection, correct identification and correct threat evaluation

Rationale For Selection: This is a measure of the completeness of the system and essentially is the fraction of all attacks for which definite warning is given.

(b) Probability of either false alarm, incorrect identification or incorrect threat evaluation

Rationale For Selection: This is a measure of the system and essentially is the fraction of all warnings which are ill defined.

(c) Reaction time, which is defined as the time elapsed from the commencement of an attack to warning of it

Rationale For Selection: This is a measure of the speed of the system.

(d) Fraction of the required time which a system is able to monitor for the phenomena to be detected

Rationale For Selection: This is a measure of the dependability of the system.

(e) Availability

Rationale For Selection: This is a measure of the presence or existence of the system and reflects its susceptibility to destruction or complete negation by countermeasures.

(f) Accuracy

Rationale For Selection: This is a measure of the quality of correctness or freedom from error. It is also an estimate of the ability of the sensor system to track a signal source.

(g) Resolution

Rationale For Selection: This is a measure of the accuracy with which the relative position of two or more signal sources in space can be unambiguously determined. In the operational world, resolution indicates the ability of the sensor system to determine the size of a raid following its detection.

(h) Delay time, which is defined as that interval from initial detection to first weapon assignment when the task force is in readiness condition one

(3, 12)

AIRBORNE ATTACK AND SURFACE ATTACK

MOE REVIEW NO. (3,12)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Study of Land/Air Trade-Offs (Short Title: SLAT), Vol. I Summary and Vol. VI The Evaluation Summary
3) Authors: W.W. Fain and J. Wilson
4) Report Number: NWAG Study No. 64 (Vol. I AD-508 990, Vol. VI AD-508 997)
5) Date: March 1970
6) Classification: Secret
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: The Study of Land/Air Trade-Offs (SLAT) is an evaluation of the relative cost and effectiveness of tactical air and ground forces in a specific tactical situation. The two basic tasks of the study are an analysis related to a current force mix problem involving tactical air and ground forces using already developed models of air and tactical warfare, and a comparison of simulated battles with historical records of daily casualties and unit personnel strength, and the other based on best estimates of weapon composition, unit posture and fire-power potential.
9) Descriptors: Airborne attack, aircraft, firepower, force allocation, Lanchester equations, personnel, resources, surface attack, surface target, survivability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force
2) Function: Airborne Attack and Surface Attack
3) Applicable Situation: Evaluation of the combined performance of ground and tactical air forces in an attack against an opposing ground and tactical air force
   3.1) Criterion For Success: Destruction of target
   3.2) MOE Selected: Kill rate, expressed in fraction of target unit strength destroyed per 24 hours of combat

MOE REVIEW NO. (3,12)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Study of Land/Air Trade-Offs (Short Title: SLAT), Vol. I Summary and Vol. VI The Evaluation Summary
3) Authors: W.W. Fain and J. Wilson
4) Report Number: NWAG Study No. 64 (Vol. I AD-508 990, Vol. VI AD-508 997)
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9) Descriptors: Airborne attack, aircraft, firepower, force allocation, Lanchester equations, personnel, resources, surface attack, surface target, survivability

B. EFFECTIVENESS MEASUREMENT

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2) Function: Airborne Attack and Surface Attack
3) Applicable Situation: Evaluation of the combined performance of ground and tactical air forces in an attack against an opposing ground and tactical air force
   3.1) Criterion For Success: Destruction of target
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Rationale For Selection: This measure is related to the weapon composition and ammunition expenditure of the firing unit and the posture of the target unit. It is also a useful tool for examining weapon and force trade-offs.

(3, 20)

AIRBORNE ATTACK AND RECONNAISSANCE/INTELLIGENCE

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Weapons Center, China Lake, California
2) Report Title: Candidate Measures of Effectiveness for Air Strike Systems
3) Authors: A. H. Goettig, A. J. Hugo and L. G. LaMarca
4) Report Number: NWC TP 4687 (AD-505 598)
5) Date: September 1969
6) Classification: Confidential
7) Project Number: AIRTASKS 30303/216/69 F32-411-001 and 30303/216/69 F20-311-003 (Naval Air Systems Command and Naval Material Command)
8) Abstract: This report derives and discusses a number of measures that might be useful for comparing the effectiveness of air strike systems. These measures of effectiveness (MOE's) were inferred by considering the offensive air-to-surface missions the strike forces should be prepared to accomplish. The MOE's are not restricted to those for which explicit data are expected to be available. Two approaches are taken. The first derives various MOE's for each mission directly from the objectives of the missions. The second derives MOE's by introducing the idea of tactical advantage of corresponding elements of the opposing forces.
9) Descriptors: Aircraft, air superiority, antiair warfare, attrition, cargo ship, close air support, fire support, intelligence, interdiction, reconnaissance, resources, supply, tactics, task force, transportation system

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force and System
2) Function: Airborne Attack and Reconnaissance/Intelligence

3) Applicable Situations:

3.1) Type: Evaluation of air strike force performance in own-force-defense (OFD) missions

3.1.1) Criterion For Success: Gain and maintain the security of a carrier task force (CTF) in the area of operation

3.1.2) MOE's Selected:

(a) Time to secure operating area

Rationale For Selection: This measure is directly related to the own-force-defense mission objective and emphasizes that (1) OFD is conducted as the basic step to pursuing the primary CTF objectives, and (2) an effective CTF should be able to conduct this mission quickly

Limitations And Assumptions:

(1) This measure does not include consideration of the duration that the operating area is secured.

(2) For critical OFD missions, which involve sudden and unavoidable threats to the CTF, the emphasis on time that this measure provides is very appropriate.

(3) The definition of a secure operating area involves determining the reduction in enemy offensive capability that is necessary before the CTF's own defense system can be expected to prevent incapacitating damage as a result of enemy attacks.

(b) Long-term reduction in threat to the operating area per unit time

Rationale For Selection: This measure is directly related to the own-force-defense mission objective and explicitly includes some of the mission features that address the nature

of damage required from effective OFD systems. This measure avoids the necessity of defining what constitutes a secure operating area but otherwise requires consideration of the same factors as the preceding measure, plus emphasizing the need for long-term damage and the necessity for being able to determine what reduction in threat has been achieved.

Limitations And Assumptions:

(1) This measure may preclude the use of weapons that cause only subtle damage to targets.

(c) Reduction in own-force-defense effort required per unit time

Rationale For Selection: This measure acknowledges that OFD missions may need to be conducted over long periods of time as an enemy rebuilds or repairs his offensive capability.

Limitations And Assumptions:

(1) This measure emphasizes the effort the CTF must expend rather than the damage done to the enemy's offenses.

(d) Intelligence required per strike

Limitations And Assumptions:

(1) There is no direct relationship between this measure and OFD objectives, but it does reflect several of the OFD mission features. Typical OFD targets are usually well defended and OFD missions may be conducted before large numbers of tactical reconnaissance (TR) missions can be conducted (or it may be

undesirable to conduct TR missions). Because of these features, the effectiveness of systems for OFD will depend to a certain extent on the amount of intelligence that is required for them to be used.

(2) This measure is generally inappropriate as a single measure but might be used as a "tie-breaker" when competing systems appear to be very similar with respect to some other measure that is closely related to the mission objective.

(3) This measure provides no assurance that OFD objectives are achieved.

3.2) Type: Evaluation of air strike force performance in defense-busting (DB) missions

3.2.1) Criterion For Success: Reduce attrition in subsequent air operations by achieving and maintaining air superiority

3.2.2) MOE's Selected:

(a) Long-term reduction in enemy antiair warfare capability per strike

Rationale For Selection: This measure is directly related to the DB mission objective of "achieving and maintaining air superiority," because reductions in enemy AAW capability are necessary to achieving air superiority.

Limitations And Assumptions:

(1) The meaning of "enemy AAW capability" is not explicit in the statement of this measure; when DB missions are considered in context with the other strike mission, it is the capability of the enemy to cause attrition of friendly aircraft striking primary targets on other missions

(2) It is the attrition-producing potential of enemy defenses that should be considered when using this measure, rather than just a count of defensive units destroyed.

(3) This measure requires consideration of the weapons and tactics available for use on other missions conducted by the CTF in order to estimate the attrition-producing potential of various enemy defensive units.

(b) Mean time between defense-busting strikes

Rationale For Selection: This measure is useful in monitoring system performance or in evaluating systems by war games.

Limitations And Assumptions:

(1) By looking at the mean time between DB strikes to compare two systems, it is necessary to assume that an operational commander has made "best possible" decisions with regard to when and where DB strikes are needed. When such an assumption is reasonable, this measure will accurately reflect the relative effectiveness of two systems in conjunction with systems used for other strike missions.

(c) Reduction in en route attrition on other strikes

Rationale For Sel[illegible] This measure may be used to determine desirability of designing a system for use against one type of defense or another.

Limitations And Assumptions:

(1) Attrition is ignored in the target area.

(d) Change in effort required to maintain low attrition on direct routes to targets

Rationale For Selection: This is a comparative measure because it considers only the change in effort required to maintain low-attrition routes to targets.

Limitations And Assumptions:

(1) This measure assumes a "worst case" condition. By considering only "direct routes" to targets, this measure assumes that strike forces would not use alternative routes to force an enemy to disperse his defenses. Limiting consideration to only direct routes would simplify calculations, however, the "worst case" aspects of this measure can be minimized or eliminated by compensating assumptions regarding distribution of enemy defenses.

(2) This measure does not explicitly consider the initial effort required to establish low-attrition routes to targets.

(3) This is a comparative measure because it considers only the change in effort required to maintain low-attrition routes to targets.

(e) Change in time to secure air superiority en route to and at target areas

Rationale For Selection: This measure is worthy of strong consideration when comparing DB systems because it addresses one of the key features of urgent DB missions; that is, it is highly desirable to be able to quickly

secure air superiority en route to a particular target even though it may not be of long-term endurance.

Limitations And Assumptions:

(1) This measure neither considers nor provides assurance that the desired long-term effects on enemy defenses would be included in comparisons of weapons on the basis of this measure.

(2) This measure primarily reflects that DB missions are only a necessary step sometimes required before strikes on primary targets can be conducted and that the sooner the defense level can be reduced the sooner the CTF can pursue its primary objectives.

(3) This measure does not ensure consideration of maintaining air superiority.

3.3) Type: Evaluation of air strike force performance in defense - suppression (DS) missions

3.3.1) Criterion For Success: Reduction of the overall attrition of strike forces

3.3.2) MOE's Selected:

(a) Change in number of aircraft lost to enemy action as a result of defense-suppression efforts

(b) Reduction in overall attrition per strike

Limitations And Assumptions:

(1) It is tacitly assumed here that the effectiveness of the primary strike will be considered constant when calculating (or measuring) the attrition.

(c) Decreased intensity of defenses during strikes

Limitations And Assumptions:

(1) For this MOE it is assumed that attrition to strike forces varies with the intensity of defense activity.

(2) The effectiveness of the primary force is assumed to be equal for each suppression concept considered, thus being eliminated as a factor in the defenders' motivation.

(3) This MOE tends to ignore such systems as ECM.

(d) Increased probability of achieving the supported mission's objectives

Limitations And Assumptions:

(1) The reduction in attrition is important only for the primary strike force and then only before weapons are delivered.

(e) Degree to which optimum tactics can be used against defended targets

3.4) Type: Evaluation of air strike force performance in close-air-support (CAS) missions

3.4.1) Criterion For Success: Provide assistance to friendly ground forces in achieving their objectives by helping to minimize attrition

3.4.2) MOE's selected:

(a) Reduction in overall losses to friendly forces while they are being assisted in: (1) holding a position, (2) gaining territory, (3) reducing enemy forces and material, or (4) retreating

(b) Response time, i.e., the time between the initial call for support (by ground forces) and the arrival of support in the objective area

Limitations And Assumptions:

(1) Long-term benefits of slower but more lethal weapons may be overlooked.

(c) Ratio of the product of our fire support time and the duration of support to the response time

Rationale For Selection: This measure provides a handle on effectiveness through the offensive potential of candidate systems.

Limitations And Assumptions:

(1) It is implicit here that friendly casualties will be reduced in some fixed relationship to the losses or possibility of losses to the enemy.

(2) It is implied that enemy losses are proportional to the added firepower provided to friendly forces.

(d) Percent of time the system can be used

Rationale For Selection: This measure considers the availability of candidate systems for use when needed.

(e) Time for ground forces to achieve their objectives

Rationale For Selection: This measure relates the achievement of CAS objectives to the time it takes the ground forces to achieve their objectives. This, then is a measure of the assistance afforded. The sooner that overall success is achieved by the ground forces, the greater has been the assistance provided by the CAS system in question.

3.5) Type: Evaluation of air strike force performance in friendly-force-defense (FFD) missions

3.5.1) Criterion For Success: Reduction of friendly force attrition by attacking the enemy's long-range offensive capability

3.5.2) MOE's Selected:

(a) Reduction in losses to friendly forces

Limitations And Assumptions:

(1) The manner in which this measure is worded tends to make it a historical or after-the-fact measure, where it is possible to count the number of losses sustained during a battle or enemy attack. Even though the measure is

basically historical, it can be used in a predictive manner through the use of war games and simulated battles.

(2) The predictive value of this measure would be very dependent on the validity of the data used in the simulation and the ability of the simulation to reflect the many interactions between opposing forces during the course of a battle.

(b) Change in friendly casualties per unit time

Rationale For Selection: This measure examines the rate at which casualties are sustained rather than to just count total casualties at the end of some operation.

(c) Reduction in enemy's potential to produce casualties in battle areas

Rationale For Selection: This measure is appropriate for comparing a wide variety of systems. It also allows use of computations for predicting the likelihood of denying or inhibiting the enemy's use of his resources and applying a factor that reflects the "casualty-producing potential" of the various targets that are attacked.

(d) Ratio of the product of our fire support and the duration of support to the response time

Limitations And Assumptions:

(1) This measure applies to the FFD mission on the assumption that friendly losses are reduced if we are firing back at the enemy.

(2) This measure is applicable in limited but critical circumstances, that is, when an enemy initiates a long-range attack on our positions and our forces will benefit from an extended suppressive effect.

(e) Targets destroyed per unit of time

Rationale For Selection: The use of this measure avoids the difficulties of simulating the interactions between opposing forces and therefore requires fewer data and/or fewer assumptions to derive a quantitative value.

3.6) Type: Evaluation of air strike force performance in interdiction--fixed-target (I-FT) missions

3.6.1) Criterion For Success: Reduction of the flow of enemy resources between sources of supply and the battlefield by attacking the transportation systems

3.6.2) MOE's Selected:

(a) Reduction in goods reaching the battle area

Rationale For Selection: This measure is directly related to the objective of the mission since it addresses the primary purpose of the mission, that is, reduction in the flow of goods. It also specifies where it is important to carry out the measurement, in the battle area.

Limitations And Assumptions:

(1) This measure implies that the details of what is happening in the transportation system itself are of no particular significance, other than how they affect goods reaching the battle area.

(2) Although not stated explicitly in the measure, it is necessary to select an appropriate time interval in which to measure the relative effects of two competing systems.

(3) This measure should be relatively easy to utilize in simulations and mathematical models, since it is typically possible

to make specified measurements at desired points, even in a very complex system. As a measure for use in actual combat situations, its utility is limited by the ability to make the required measurements.

(4) This is not a direct measure of the enemy's ability to fight unless battle area stockpiles are considered.

(b) Reduction in capacity of the transportation system per strike

Rationale For Selection: The use of this measure has the advantage of directing attention to fixed targets in the total transportation system used to supply goods to the battle area and therefore provides additional perspective over measures such as "probability of dropping span of bridge," "probability of cutting the width of road," or "time that a road, bridge, railroad, or canal is unusable."

Limitations And Assumptions:

(1) This measure is appropriate if a reduction in the capacity of a transportation system will in turn affect the goods reaching the battle area.

(2) The validity of this measure depends on the ratio of capacity of the system needed to support the battle area to the total capacity of the system. If this ratio is close to or greater than 1, there could be a definite reduction in enemy supply rates with each attack.

(3) This measure includes a specified interval for measurement, that is, the time it takes to conduct a single strike, and therefore has usefulness in comparing two systems that do the same thing.

(4) The measure provides no assurance that either of two systems will be effective in meeting mission objectives unless it is known that they will be used in circumstances where the ratio discussed above is greater than or near 1. If that ratio is much less than 1, each strike would not reduce the supply of resources, but would affect only "unused" capacity of the system. In this case, then, the measure provides only the relative efficiency of systems for reducing the capacity of a transportation system. The value of the ratio then, determines whether this is an effectiveness measure or an efficiency measure.

3.7) Type: Evaluation of air strike force performance in interdiction - search-and-attack (I-SA) missions

3.7.1) Criterion For Success: Reduction of the flow of enemy resources between sources of supply and the battlefield by attacking the cargo and cargo carriers en route

3.7.2) MOE's Selected:

(a) Reduction in goods reaching the battle area

<u>Limitations And Assumptions</u>:

(1) This is not a direct measure of the enemy's ability to fight unless battle area stockpiles are considered.

(b) Reduction in capacity of the transportation system per strike

(c) Goods destroyed en route

Limitations And Assumptions:

(1) This measure provides very little perspective or ability to compare a variety of systems that could be used for interdiction.

(2) The usefulness of this measure is limited to systems that are devoted only to the destruction of goods.

(3) This measure provides no idea of the effect on the enemy's ability to fight.

3.8) Type: Evaluation of air strike force performance in strategic-support (SS) missions

3.8.1) Criterion For Success: Progressive disablement of the enemy's war-making capability to a point where he no longer retains the ability or the will to wage war

3.8.2) MOE's Selected:

(a) Percentage of enemy's total resources denied to him

Limitations And Assumptions:

(1) To use this measure it would be necessary first to calculate the extent of the enemy's total resources (including foreign aid).

(b) Reduction in material that can be sent to the battle area

Limitations And Assumptions:

(1) This MOE requires a detailed model of the enemy's supply and manufacturing system, and it equates resources with the ability to wage war.

(c) Ratio of the rate of destruction of strategic support targets to the rate of rebuilding strategic support targets

Rationale For Selection: This measure can be used to determine if the rate of target destruction is sufficient to reduce the enemy's ability to wage war in the time available for conducting the SS mission.

Limitations And Assumptions:

(1) This MOE requires assumptions about the enemy's ability to rebuild SS targets as well as a model computing our ability to destroy these targets.

(2) It is assumed that when the enemy is losing SS targets faster than he can rebuild them, his ability to wage war is being destroyed.

(d) Reduction in basic necessities available to population

Limitations And Assumptions:

(1) This measure is related to the SS objective by assuming that if the quantity of basic consumer necessities is reduced sufficiently, enemy civilians will no longer desire to support the war effort, and/or that if the quantity of consumer necessities is reduced further, enemy civilians will be physically unable to support the war effort.

(e) Ratio of "cost of target" to the "cost to kill target"

Limitations And Assumptions:

(1) The assumption that ties this MOE to the mission objective is that unless the enemy's monetary resources are depleted before ours, then rather than have his will or ability to wage war destroyed, our will or ability will be destroyed.

3.9) Type: Evaluation of air strike force performance in tactical-reconnaissance (TR) missions

3.9.1) Criterion For Success: Obtain (1) information on current or potential enemy activity, (2) information on the meteorological and geographical characteristics of an area, and (3) bomb damage assessment

3.9.2) MOE's Selected:

(a) More rapid and reliable information per supported sortie

(b) Percent of time the needed information is obtained, processed, and made available

(c) Percent of needed information that is obtained, processed, and made available

(6, 16)

MINE COUNTERMEASURES AND AMPHIBIOUS ASSAULT

MOE REVIEW NO. (6,16)-1

A. STUDY DESCRIPTION

1) Originating Activity: Presearch, Incorporated, Silver Spring, Maryland
2) Report Title: MCM Operations in Small Amphibious Assaults
3) Authors: H.R. Burt, J.W. Campbell, T.C. Cox and L.S. Freeman
4) Report Number: Technical Report No. 185 (AD-515 907)
5) Date: 2 July 1970
6) Classification: Secret
7) Contract: N00600-68-C-1282 (U.S. Navy Ship Research and Development Laboratory)
8) Abstract: This report presents the results of an analysis of mine countermeasures operations in amphibious assaults of the Marine Expeditionary Brigade (MEB) and Marine Expeditionary Unit (MEU) size. The MEB assault considered in this study is examined in four different amphibious ship loadouts. These include a composition felt to be a representative loadout; a concentrated loadout, utilizing a few large ship types; a distributed loadout, in which the landing force is distributed among several smaller ships; and a special purpose loadout, in which LPH/LHA type ships are predominant. A single loadout is considered for the smaller MEU assault. Mine countermeasures options considered are: helicopters for moored mine clearance: MSO as influence countermeasures units: and pressure mine sweepers for influence clearance.
9) Descriptors: Amphibious operation, assault ship, mine, mine countermeasure, minehunting, minesweeping

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force
2) Function: Mine Countermeasures and Amphibious Assault
3) Applicable Situation: Evaluation of the effectiveness of mine clearance operations in preparation for amphibious assaults

3.1) Criterion For Success: Clearance of minefield

3.2) MOE's Selected:

(a) Probability of assault success for a given level of countermeasures effort

(b) Probability that amphibious ship casualties do not result in the loss of troops or cargo sufficient to jeopardize the mission

(8, 18)

SUBMARINE ASW AND COMMAND AND CONTROL

MOE REVIEW NO. (8,18)-1

A. STUDY DESCRIPTION

1) Originating Activity: Operations Research, Incorporated, Silver Spring, Maryland
2) Report Title: The ASW Classification Problem in a Multicontact Environment - A Queuing Approach
3) Authors: P.M. Tullier and D. W. Walter
4) Report Number: Technical Memorandum No. 138-71 (AD-890 720)
5) Date: 20 December 1971
6) Classification: Unclassified
7) Contract: N00014-71-C-0408 (Office of Naval Research)
8) Abstract: The passive classification process aboard a submarine is studied. In particular, the operations of the sonars in a multicontact environment are treated as a time-shared processing system. The processors are the passive sonars and the customers are the sonar contacts. This interim report gives the rationale for describing the system in this manner. The queuing system equations are not yet formulated. General measures of effectiveness are presented which can be obtained through the queuing approach.
9) Descriptors: Antisubmarine warfare, classification, command and control, detection, localization, queuing, sonar, submarine, submarine attack, undersea warfare

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Submarine ASW and Command and Control
3) Applicable Situation: Evaluation of the performance of a shipboard command and control system in the detection, localization, classification and attack of hostile submarines
   3.1) MOE's Selected:
      (a) Probability that a target in range for its characteristics (noise level, etc.) is not picked up before it leaves the area given a weighted sum of targets and their priorities

(b) Probability that a target is not picked up until t time units after it was "available" given a weighted sum of targets and their priorities

(c) Probability of losing a contact of priority before complete classification given a weighted sum of targets and their priorities

(d) Expected number of contacts lost in a given time given a weighted sum of targets and their priorities to start with

(e) Expected time to classify given a weighted sum of targets and their priorities in the system to start with

(f) Expected number of targets in a given class in the system at any time

(g) Expected value of a weighted sum of targets and their priorities

(h) Expected total time a target is in the system

(9, 10)

SUBMARINE ATTACK AND SURFACE ASW

MOE REVIEW NO. (9,10)-1

A. STUDY DESCRIPTION

1) Originating Activity: TRW Systems Group, Washington Operations, Washington, D.C.
2) Report Title: "ASW System Simulations for Surface Escorts and Submarines"
3) Authors: R. E. Arison and L. A. Franz
4) Source: U. S. Navy Journal of Underwater Acoustics, Vol. 20, No. 3 (Supplement) (AD-512 800)
5) Date: July 1970
6) Classification: Confidential (NOFORN)
7) Abstract: With the convocation of SPECON (Systems Performance Effectiveness Conference, 1965), the Navy Materiel Command introduced a formalized program of total system analysis which set the framework for a quantitative approach to system effectiveness prediction and evaluation. The subsequent application of system analysis to the ASW problem resulted in the development of several techniques ranging in complexity from detailed subsystem simulation to an analysis of force level requirements. This paper discusses this application of systems analysis and provides a description of two ASW encounter models; one simulating destroyer escort and the other submarine ASW missions. Both models were developed in response to specific requirements of the Manager, Anti-Submarine Warfare Systems Project.
8) Descriptors: Antisubmarine warfare, convoy escort, fire control, hit probability, kill probability, Monte Carlo method, screen, sonar, submarine, surface ship, torpedo

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force and Subsystem
2) Function: Submarine Attack and Surface ASW

3) Applicable Situations:

3.1) Evaluation of surface escort performance in convoy defense against submarine attack

3.1.1) Criterion For Success: Prevention of submarine penetration of a convoy

3.1.2) MOE's Selected:

(a) Probability that the submarine is killed

(b) Probability that the submarine successfully penetrates the screen

(c) Expected number of escort losses to submarine attacks

3.2) Type: Evaluation of the attack capability of a submarine weapon system

3.2.1) MOE's Selected:

(a) Probability of weapon malfunction

(b) Probability of target miss not caused by weapon failure

(c) Probability that target is hit

(9, 12)

SUBMARINE ATTACK AND SURFACE ATTACK

MOE REVIEW NO.(9,12)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Radiological Defense Laboratory, San Francisco, California
2) Report Title: Ship Vulnerability Methodology for the ASW Force Level Study
3) Authors: R. E. Austin, D. Roudebush, C. V. Smith and J. E. Taylor
4) Report Number: NRDL-TR-68-103 (AD-394 166)
5) Date: 19 December 1968
6) Classification: Secret (NOFORN)
7) Project Number: NSSC, Subproject S4627 002, Task 11607 (Naval Ship Systems Command)
8) Abstract: This report presents the development and initial test of the NRDL ship vulnerability methodology for the ASW Force Level Study. The prototype NRDL Ship Vulnerability Model provides the principal source of data for the methodology. These data are then analyzed in a probabilistic fashion to provide values for measures of effectiveness.
9) Descriptors: Damage assessment, mine, Monte Carlo method, submarine attack, surface attack, surface ship, torpedo, vulnerability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Submarine Attack and Surface Attack
3) Applicable Situation: Evaluation of the vulnerability of naval ships when attacked by specified enemy weapon systems
   3.1) MOE's Selected:
      (a) Probability that a ship will be in a given condition after a specified number of weapon hits

Rationale For Selection: This MOE determines the mission-keeping capabilities of a ship after it has been attacked.

(b) Expected off-line time, which is defined as the time it takes a ship, after it has been hit with one or more weapons to travel to a repair facility, be repaired and return back to the operational area, i.e., the sum of the transit time and the expected repair time

(10, 12)

SURFACE ASW AND SURFACE ATTACK

MOE REVIEW NO. (10,12)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Measures of Effectiveness for Harbor Defense
3) Author: A.M. Bottoms
4) Report Number: CEG Study No. 536
5) Date: 12 October 1954
6) Classification: Confidential
7) Abstract: Measures of effectiveness to assist in the evaluation of harbor defense systems and components, and to provide a basis for the planning of harbor defense exercises are developed in this study. Methods of computation of these measures and illustrative examples of the treatment of data are shown.
8) Descriptors: Antisubmarine warfare, barrier, command and control, detection, harbor defense, surface attack

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Surface ASW and Surface Attack
3) Applicable Situations:
   3.1) Type: Evaluation of a harbor defense system whose major functions are detection of raid, recognition and action on a raid, and prevention of a raid
      3.1.1) Criterion For Success: Prevention of raids on port facilities and shipping
      3.1.2) MOE's Selected:
         (a) Probability of raid prevention
         Rationale For Selection: The harbor defense system will reduce the amount of damage caused by

a given type of sneak raider if it prevents some of its raids.

(b) Expected damage per raid type attempted

Rationale For Selection: If all raid types had the same damage potential, the overall measure of raid preventing capability would also be the measure of damage minimizing capability.

(c) Expected damage to the defended area per raid attempted

Limitations and Assumptions:

(1) This measure of effectiveness cannot be used if the probability distribution of raid types is not known or cannot be reliably estimated. This may well be the case, since the probability that a raid will be a given type is determined largely by the enemy.

(d) Damage profile vector, defined to be a vector whose i^{th} component represents the expected damage per raid type i attempted

Rationale For Selection: This measure provides a characterization of the defensive capability of the system. It is of value since it can demonstrate whether the expected damage for a given type of raid is too high, and can suggest changes to be instituted to improve the ability of the system to prevent raids of a given type.

(e) Raids attempted per raid reaching vicinity of harbor

Rationale For Selection: This is a measure of the psychologically deterring effect of the defense of the harbor on the raider

Limitations And Assumptions:

(1) While it is anticipated that this quantity will decrease as the probability of destroying

an attacking raider increases, no true relationship can be established. Operational data is lacking and cannot be simulated.

3.2) Type: Evaluation of the major components of harbor defense systems

3.2.1) MOE's Selected:

(a) Probability that a sneak craft of a given type will be detected by at least one component in the harbor defense detection system

Rationale For Selection: This is a partial measure of the effectiveness of the detection step.

(b) Probability that a detected raid is acted on

Rationale For Selection: This is a partial measure of the effectiveness of the recognition and action step which takes place in the harbor defense combat information center.

(c) Kill probability of the action taken against the specific type of raid

Rationale For Selection: This is a partial measure of the effectiveness of the destruction step in the harbor defense system.

(d) Weapon kill probability for the given type of raid

Rationale For Selection: This measure is useful in comparing various weapons against the same sneak craft.

(e) Average system delay time, defined as the average time elapsed between the moment the raid crosses the outermost barrier and the moment the raid is prevented

Rationale For Selection: As time elapses beyond the moment a raid reaches the outermost barrier, the harbor defense system must act with

sufficient promptness to prevent the raid before it reaches the weapon release point. Any undue delay in accomplishing any act in the sequence leading to the prevention of a raid can contribute to the failure of the defense system. Consequently, the average delay occurring as a result of the activities of each of the major components of the system (detection, action, weapon) is also an important measure of the effectiveness of the component.

Limitations And Assumptions:

(1) The average system delay time cannot generally be obtained by adding the component delay times because the average system delay and average action delay are computed only for prevented raids.

(2) The average action delay time is computed for those raids acted on by the evaluator, whether or not they are prevented, and the average detection delay time for all detected raids, authentic or not.

(3) The sum of the component averages (i.e., average detection delay time, average action delay time, average weapon delay time) is usually greater than the average system delay time.

3.3) Type: Evaluation of the detection component of harbor defense systems

3.3.1) MOE's Selected:

(a) Probability of detection of a given target

(b) Effective search (or sweep) width

(c) Sweep-width, defined as the area under the curve of the probability of detection as a function of the lateral range (closest approach abeam) from the detection gear to the target

Rationale For Selection: Sweep-width can be thought of as the width of a channel searched by an idealized detection instrument which detects all targets within the channel and none outside the channel, but which detects as many targets as the actual detection instrument under discussion does, both within and outside the channel.

(d) Effective search rate, defined as the product of the effective-search width and the relative speed of the searching vehicle with respect to the targets

3.4) Type: Evaluation of the combat information center component of harbor defense systems

3.4.1) MOE's Selected:

(a) Probability of initiating an attack on the detected raid

(b) Probability that the evaluator is presented correct information on weapons

3.5) Type: Evaluation of the weapon components of harbor defense systems

3.5.1) MOE Selected:

(a) Kill probability of the weapon system for the specific type of raid

(11, 12)

SURFACE AAW AND SURFACE ATTACK

MOE REVIEW NO. (11,12)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Ordnance Laboratory, White Oak, Maryland
2) Report Title: Effectiveness Study of a Coastal Gunboat in a Southeast Asia Theater
3) Authors: J. L. Franklin, A. Crane, M. Kasper, F. Cooke and W. Grimes
4) Report Number: NOLTR 69-73 (AD-504 891)
5) Date: 8 April 1969
6) Classification: Secret (NOFORN)
7) Project Number: NAVORD SYSCOM ORDTASK ORD-083-030/092-1/F008-0125 Problem 2 (Naval Ordnance Systems Command)
8) Abstract: This report presents a study of an ordnance suit for the PTF (NASTY) patrol craft conducted by the Naval Ordnance Laboratory Small Craft Armament Analysis Team. The report considers three separate targets: enemy gunboats, shore bombardment, and aircraft. The effectiveness of rockets, guns, and guided missiles against these targets is determined.
9) Descriptors: Aircraft, amphibious operation, antiair warfare, hit probability, kill probability, missile, Monte Carlo method, patrol craft, surface attack, surface ship, weapon mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Surface AAW and Surface Attack
3) Applicable Situations:
   3.1) Type: Evaluation of the effectiveness of patrol craft anti-boat weapons in a two-boat engagement
      3.1.1) MOE's Selected:
         (a) Probability that weapon kills the enemy craft during the engagement

(b) Duration of the engagement

(c) Average range at which the enemy craft sustains lethal damage from the weapon

3.2) Type: Evaluation of the effectiveness of patrol craft antiair weapons

3.2.1) Criterion For Success: Destruction of target

3.2.2) MOE Selected:

(a) Single pass probability of at least one hit on the aircraft

3.3) Type: Evaluation of the effectiveness of patrol craft weapons in shore bombardment

3.3.1) Criterion For Success: Inflict troop casualties

3.3.2) MOE's Selected:

(a) Expected number of troops killed in the target area

(b) Fraction of casualties

(11, 18)

SURFACE AAW AND COMMAND AND CONTROL

MOE REVIEW NO. (11,18)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Postgraduate School, Monterey, California
2) Report Title: REACT (Response Evaluation Against Current Threats), A Detailed DDG-2 TARTAR Weapons System Simulation Model in GPSS/360
3) Author: M.E. Fitzgerald
4) Report Identification: Thesis for the Masters of Science in Operations Research, (AD-512 627)
5) Date: September 1970
6) Classification: Secret
7) Abstract: This thesis contains a description of the REACT (Response Evaluation Against Current Threats) model. REACT is a computer simulation of a target processing system of the DDG-2 class Weapons Direction System Mark 4. The model is programmed in GPSS/360 and includes sufficient detail so that various questions of tactical performance and/or command and control doctrine can be investigated. Several potential applications of this model are discussed. Including in an appendix to this thesis is a demonstration of model utility that investigates a launcher loading doctrine for the MARK II Guided Missile Launching System.
8) Descriptors: Antiair warfare, command and control, fire control computer, Monte Carlo method, surface-to-air missile

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Surface AAW and Command and Control
3) Applicable Situation: Evaluation of a missile launcher loading doctrine
   3.1) MOE Selected:
      (a) Mean number of missiles fired

(12, 16)

SURFACE ATTACK AND AMPHIBIOUS ASSAULT

MOE REVIEW NO. (12,16)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: Landing Force Support Ship (LFS) Study
3) Authors: J.L. Cotton and R. Struyk
4) Report Number: SEG Study No. 2 (AD-505 218)
5) Date: 1 March 1968
6) Classification: Secret (NOFORN)
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: This report examines a non-nuclear threat, in the form of 2 different enemy target arrays, assumed to oppose the Marine forces in a regimental sector of a major amphibious landing. Calculated performance data of Naval guns is used in a computerized model against these assumed target arrays. From the results of this analysis, combinations of guns are examined at varying levels of 10-year peace time costs, hypothetical marine casualties, or both. The effect of Marine artillery support on the target arrays is included when examining all fire support systems except air. This report also analytically examines calculated performance data of the still to be developed Sea Lance Missile System and current fleet cruisers and destroyers when they are used separately against the same regimental target arrays used in the analysis. The new destroyer (DX) concepts are examined analytically against a target array of battalion size in conjunction with artillery, with and without additional fire support from LFS guns. The carrier-based attack aircraft are examined by use of a simulation approach against the D-day target array as used for the regimental sector analysis of Naval guns. Comparisons are presented in terms of hypothetical casualties and 10-year peace time costs. An interaction of artillery, Naval guns, missiles and aircraft is not included.

9) Descriptors: Amphibious operation, cost, cost effectiveness, firepower, fire support, gun, kill, kill rate, lethality, missile, naval gunfire support, surface ship, surface-to-surface missile, target mix, weapon mix

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force and System
2) Function: Surface Attack and Amphibious Assault
3) Applicable Situations:
   3.1) Type: Evaluation of shore-based weapon kill capability against marine assault forces
      3.1.1) MOE Selected:
         (a) Average rate (casualties per minute) at which casualties are inflicted on friendly forces from the time the enemy weapon or force opens fire until it runs out of ammunition or withdraws

         Rationale For Selection: This is a measure of lethality potential in terms of the number of marine casualties (casualty rate) a weapon is capable of inflicting on the advancing marine forces.

         Limitation And Assumptions

         (1) Casualty rate should vary during coordination, spotting and fire for effect of Naval guns.
         (2) The firing cycle of weapons varies considerably during their lifetime, hence the casualty rate of the marines would actually fluctuate from possibly some very high number to zero casualties per minute even without the weapon being under fire.

3.2) Type: Determination of ship weapon system capability to provide neutralization fire to prepare beach and helicopter landing areas

3.2.1) MOE's Selected:

(a) Number of rounds required for preparation fire on a specified area

(b) Number of ships required, defined as the ratio of the number of rounds delivered to the number of rounds required

3.3) Type: Evaluation of ship fire support performance in assisting marine landing forces

3.3.1) MOE's Selected:

(a) Reduction in the number of marine casualties due to action of enemy weapons or forces

(b) Number of combat-capable marines on the beachhead at the end of the assault phase

3.4) Type: Evaluation of the result of a duel between an attacker and a defender

3.4.1) MOE Selected:

(a) Combat ratio, which is the ratio of the attacker combat power to the defender combat power. (Combat power is defined as the product of firepower and a tactical factor. The latter accounts for the influence of fields of fire, obstacles, cover, concealment, visibility, terrain, surprise, deployment, mobility, armor, logistics support, etc.)

<u>Rationale For Selection</u>: This measure can be used to estimate casualties.

(14, 17)

ELECTRONIC WARFARE AND NAVAL COMMUNICATIONS

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Electronics Laboratory Center, San Diego, California
2) Report Title: Computer Software Approach to Link 11 Jamming Protection
3) Authors: R.B. Lowry and L.M. Hamerman
4) Report Number: NELC 1580 (AD-519 711)
5) Date: 23 August 1968
6) Classification: Secret (NOFORN)
7) Contract: N00953-68-M-2939 (Naval Ship Systems Command)
8) Abstract: This study investigates and compares a number of redundancy techniques which can be applied to Link 11 to provide jammer resistance. The techniques may all be implemented by means of computer software, thus requiring no hardware modifications. A measure of antijamming effectiveness is developed and used to facilitate comparison of the techniques.
9) Descriptors: Communications, computer, countermeasure, data link, electronic warfare, transmitter

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Subsystem
2) Function: Electronic Warfare and Naval Communications
3) Applicable Situations:
   3.1) Type: Evaluation of the protection afforded to a data link by employment of antijamming schemes
      3.1.1) Criterion For Success: Prevention of successful jamming
      3.1.2) MOE's Selected:
         (a) Total number of jamming units (i.e., the power-bandwidth-time product required by the jammer to insure the alteration of a single bit) per frame

which the jammer must expend to insure the nullification of data transmitted in a data frame

(b) Ratio of the number of bits which must be altered by jamming to nullify the transmission to the total number of bits transmitted per message

3.2) Type: Evaluation of the transmission efficiency of a tactical data link

3.2.1) MOE Selected:

(a) Ratio of the number of actual nonredundant data bits per frame to the total number of bits per frame

(21,22)

LOGISTICS AND SHIP SUPPORT

MOE REVIEW NO. (21,22)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Naval Postgraduate School, Monterey, California
2) Report Title: Polaris FBM System: A Survey and Analysis of Support Operations
3) Authors: C. A. Luff, T. S. Rogers, Jr. and A. D. Branch
4) Report Number: (AD-375 455)
5) Date: 1963
6) Classification: Secret (NOFORN)
7) Abstract: This study presents a survey and analysis of FBM Patrol Operations and logistic support. The variables of the operation are classed as inputs in determining a measure for the operation and a functional dependence is indicated. A model for determining optimum location of Mobile Support Groups and measures of effectiveness for the SSB(N) and the Mobile Support Group are provided. Alternate approaches are suggested for further study in measuring the effectiveness of and in improving FBM warfare.
8) Descriptors: Availability, fleet ballistic missile, logistics, reliability, ship support, submarine

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Logistics and Ship Support
3) Applicable Situations:
   3.1) Type: Evaluation of logistics support contribution to the operational readiness of FBM weapon systems
      3.1.1) Criterion For Success: Maintain a high state of readiness of Polaris FBM submarines

3.1.2) MOE Selected:

(a) Operational availability of an SSB(N) on patrol, which is defined as the ratio of the number of days in the operating area that a given number of Polaris missiles are ready for firing, to the total scheduled patrol length in days

Rationale For Selection: Operational availability suggests several applications of possible usefulness and interest to planners:

(1) Operational availability may be used as the effectiveness input to a cost effectiveness study of the FBM weapon system.

(2) Operational availability for individual SSB(N)'s may be combined and averaged to determine the overall operational availability for a given Mobile Support Group location and operating area.

(3) The operational availability data for SSB(N) on patrol may be combined with data on the probability of detection of the SSB(N) in a given operating area, and probability of kill and attrition factors for the Polaris missile, to calculate the expected target destruction as a function of time.

(4) Plots of operational availability as a function of time would serve to indicate fluctuations and trends in the operation that may require remedial action or modifications to operating procedures.

(5) The operational availability measure indicates an important distinction between the concept of availability and reliability. Operational availability as defined above includes the time required to repair failures or malfunctions while operating submerged during a patrol, and includes not only considerations of the probability of failure, but also the availability of spare parts, accessibility of failed or malfunctioning equipment, level of technical training of the SSB(N) crew, and the effects of system failures and repair times on execution of the mission. It is felt that this concept gives a more meaningful interpretation of the output of the operation than does system reliability per se.

3.2) Type: Evaluation of how well a Mobile Support Group can prepare an SSB(N) for the succeeding patrol by correcting material deficiencies, installing equipment changes, and resupplying the SSB(N)'s logistic deficiencies in the execution of its mission

3.2.1) Criterion For Success: Furnish logistic support to the SSB(N) fleet

3.2.2) MOE Selected:

(a) Mobile Support Group Effectiveness, which is defined as the ratio of the product of total number of job orders completed during an SSB(N) upkeep times maximum available MSG man-hour capacity during an SSB(N) upkeep to the product of total number of job orders submitted to the MSG per SSB(N) upkeep times total MSG man-hours expended on completed job orders

Rationale For Selection: This is a measure of the effectiveness of the Mobile Support Group to prepare the SSB(N) for the succeeding patrol by correcting material deficiencies, installing equipment changes, and resupplying the SSB(N)'s logistic deficiencies in the execution of its mission.

3.3) Type: Evaluation of the maintenance and repair capability of the FBM weapon system while on patrol

3.3.1) Criterion For Success: Rapid repair of system failures while on patrol

3.3.2) MOE Selected:

(a) SSB(N) repair effectiveness, which is defined as the ratio of the product of total number of components repaired during patrol times maximum available SSB(N) man-hour capacity, to the product of number of system components that failed during patrol times total man-hours expended on repair of components

Rationale For Selection: This is a measure of the effectiveness of the SSB(N) in the maintenance and repair of the FBM weapon system while on patrol.

3.4) Type: Evaluation of the reliability of the FBM weapon system

3.4.1) Criterion For Success: Nonfailure of the system during the length of the patrol

3.4.2) MOE Selected:

(a) System reliability, which is defined as the inherent probability that the components of the FBM weapon system will remain in operation without failure for the length of the SSB(N) patrol

(1,7, 10)

AIRBORNE ASW, OCEAN SURVEILLANCE AND SURFACE ASW

3.1.1) Criterion For Success: Minimize the cost of the air ASW forces needed to fulfill the mission requirements

3.1.2) MOE Selected:

(a) Total cost of a given mix of sea-based and land-based air ASW forces which are needed to achieve a specified level of submarine attrition

3.2) Type: Evaluation of sonobuoy performance

3.2.1) MOE's Selected:

(a) Sonobuoy lifetime

(b) Detection range, which is defined as the range at which the probability of detection is 50 percent

3.3) Type: Evaluation of MAD performance

3.3.1) Criterion For Success: Detection of submarine

3.3.2) MOE's Selected:

(a) Detection range

(b) Standard deviation associated with MAD detection range

3.4) Type: Evaluation of periscope detection radar performance

3.4.1) Criterion For Success: Detection of target

3.4.2) MOE's Selected:

(a) Detection probability for a snorkeling submarine as a function of range

(b) Detection range for a surfaced submarine as a function of radar altitude

3.5) Type: Evaluation of torpedo performance

3.5.1) MOE's Selected:

(a) Endurance

(b) Maximum homing range

(c) Single shot kill probability

3.6) Type: Evaluation of an aircraft-submarine encounter

3.6.1) MOE's Selected:

(a) Probability that aircraft detects submarine

(b) Probability that aircraft attacks submarine

(c) Probability that aircraft localized submarine, given that the aircraft detected the submarine

(d) Probability that aircraft kills submarine, given

that the aircraft localized the submarine

3.7) Type: Evaluation of SOSUS performance

3.7.1) MOE's Selected:

(a) Performance index (PI) which is defined by: PI=(ambient noise level at the line frequency) + (transmission loss) - (array gain) + (operational recognition differential)

(b) Mean localization area

(c) Probability that contact is held at a random moment

(d) Mean holding time

(e) Mean recovery time

Rationale For Selection: The recovery time is a fundamental measure used in determining SOSUS contact capability, since it is a determination of the time between probable contacts.

(f) Probability of detecting a snorkel exposure

(g) Cumulative probability of detection against a single target submarine over a specified number of days

3.8) Type: Evaluation of aircraft prosecution of SOSUS contact

3.8.1) MOE's Selected:

(a) Probability of kill per prosecution

(b) Cumulative probability of kill over a specified number of days

(c) Percent of deployed submarines killed during engagement

(d) Expected number of aircraft required at the nearest base to prosecute a given submarine target

3.9) Type: Evaluation of aircraft attack capability given a flaming datum

3.9.1) Criterion For Success: Destruction of submarine

3.9.2) MOE Selected:

(a) Probability of killing submarine responsible for a flaming datum

3.10) Type: Evaluation of CVS escort force effectiveness

3.10.1) Criterion For Success: Protection of CVS

3.10.2) MOE's Selected:

(a) Probability of detection of submarine attempting to penetrate screen as a function of the escort spacing factor (ESF = total length of screen line divided by the sum of sonar sweep width)

(b) CVS survivability, which is defined as the probability the CVS will not be damaged by an attacking submarine force

(1, 8, 9)

AIRBORNE ASW, SUBMARINE ASW AND SUBMARINE ATTACK

MOE REVIEW NO. (1,8,9)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: A Simplified Anti-Shipping Campaign Model
3) Authors: J. E. Bangert, W. B. Buchanan, J. A. Howe, M. D. Miller, W. T. Sanders and T. J. Stillings
4) Report Number: CNA Research Contribution No. 100 (AD-501 837)
5) Date: October 1968
6) Classification: Secret
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: Analyses are performed using operational performance data to estimate the outcomes of three classes of war-at-sea engagements, namely: submarine ASW, air ASW and anti-shipping.
9) Descriptors: Aircraft, antisubmarine warfare, barrier, classification probability, convoy defense, detection, detection probability, kill probability, Lofar, radar, submarine, submarine attack, torpedo, transitor, visual

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System
2) Function: Airborne ASW, Submarine ASW and Submarine Attack
3) Applicable Situations:
   3.1) Type: Evaluation of the tactical situation involving SSK versus Transitor
      3.1.1) Criterion for Success: Detection and destruction of submarine
      3.1.2) MOE's Selected:
         (a) Probability of killing a transiting submarine, referred to as Weapons System Effectiveness (WSE)

(b) Exchange ratio, defined as the expected number of transitors killed per SSK lost

3.2) Type: Evaluation of the capabilities of VS and VP aircraft using Lofar radar and visual search modes to detect, localize and attack submarines

3.2.1) Criterion For Success: Detection, localization and destruction of submarine

3.2.2) MOE's Selected:

(a) Probability of aircraft attack given radar or visual detection of submarine

(b) Probability of kill given an attack engagement

(c) Aircraft kill width, defined as the aircraft radar-visual detection sweep width multiplied by the probability of attack given detection and the probability of kill given attack

(d) Expected number of submarines killed per unit time

(e) Probability of kill per snorkel period due to Lofar detection

(f) Probability of kill per transit due to Lofar detection

(g) Total one-way attrition of diesel transitors in the barrier due to the combined Lofar, radar and visual search

3.3) Type: Evaluation of Lofar field detection capability against a snorkeling diesel submarine

3.3.1) Criterion For Success: Detection of snorkeling submarine

3.3.2) MOE Selected:

(a) Probability of at least one detection by the field per snorkel period for a given buoy spacing

3.4) Type: Air and surface screen convoy defense against torpedo attacks from hostile submarines

3.4.1) Criterion For Success: Successful attack on ship

3.4.2) MOE's Selected:

(a) Expected number of merchant ships sunk per engagement

(b) Probability that the submarine is sunk in a single convoy engagement

(c) Probability that a submarine survives an on-station period

3.5) Type: Evaluation of submarine detection capability against independent and convoyed merchant ships

3.5.1) Criterion For Success: Detection of ship

3.5.2) MOE's Selected:

(a) Detection sweepwidth

(b) Probability of closure

(c) Engagement sweepwidth

3.6) Type: Evaluation of submarine attack capability against independent and convoyed merchant ships

3.6.1) Criterion For Success: Successful attack on ship

3.6.2) MOE's Selected:

(a) Probability of no hit on the ship

(b) Probability of damage to the ship

(c) Probability of sinking the ship

(d) Expected number of torpedoes fired

3.7) Type: Evaluation of convoy air screen performance

3.7.1) Criterion For Success: Denial to a diesel submarine the use of the surface before and during its attack

3.7.2) MOE's Selected:

(a) Kill sweep rate

(b) Probability of kill

(2, 3, 11)

AIRBORNE AAW, AIRBORNE ATTACK AND SURFACE AAW

MOE REVIEW NO. (2,3,11)-1

A. STUDY DESCRIPTION

1) Originating Activity: Center for Naval Analyses, Arlington, Virginia
2) Report Title: The Analysis of Future Naval Weapon Systems
3) Author: R. A. Harrison
4) Report Number: CNA Summary Report 1 (AD-500 511)
5) Date: September 1968
6) Classification: Secret
7) Contract: N00014-68-A-0091 (Office of Naval Research)
8) Abstract: This report presents the highlights of a series of studies of possible future naval weapon systems conducted at the Center for Naval Analyses from 1963 to 1968. Computer simulations of air warfare are compared to air warfare itself. Mathematical models of missile system effectiveness are derived.
9) Descriptors: Aircraft, antiair warfare, carrier, escort ship, hit probability, kill probability, missile, Monte Carlo method, ship defense, surface ship, survivability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force, System and Subsystem
2) Function: Airborne AAW, Airborne Attack and Surface AAW
3) Applicable Situations:
   3.1) Type: Evaluation of AAW performance in ship defense
      3.1.1) MOE's Selected:
         (a) Probability of survival of a CVA against an attack of a given size
         (b) Expected number of escort ships lost in a given size of attack

(c) Ratio of the U.S. Naval forces lost to the enemy air forces lost

(d) Cost effectiveness, defined as effectiveness of defenses for a given total cost

3.2) Type: Evaluation of the interceptor phase during the battle between the attacking and defensive aircraft

3.2.1) MOE Selected:

(a) Probability of one aircraft killing another on firing pass

3.3) Type: Evaluation of the shipboard defense phase, defined to start when the shipboard batteries begin firing

3.3.1) MOE Selected:

(a) Kill probability for a shipboard battery firing against a target

3.4) Type: Evaluation of the attack result phase, which consists of the detonations of the enemy weapons and the resultant damage to the task force

3.4.1) Criterion For Success: Destruction fo target

3.4.2) MOE Selected

(a) Probability that a bomb will hit a ship

3.5) Type: Evaluation of missile system performance

3.5.1) MOE's Selected

(a) Kill probability of the air-to-surface missiles (ASM) against a surface-to-air missile (SAM) battery

(b) Expected number of air-to-surface (ASM) missiles that survive the surface-to-air missile (SAM) defenses in an attack

(6, 18, 19)

MINE COUNTERMEASURES, COMMAND AND CONTROL AND NAVIGATION

MOE REVIEW NO. (6,18,19)-1

A. STUDY DESCRIPTION

1) Originating Activity: U.S. Navy Mine Defense Laboratory, Panama City, Florida
2) Report Title: Cost-Effectiveness of Navigation, Command and Control Capability for Mine Countermeaures
3) Authors: T.C. Buckley, R.T. Galloway and E. L. Sharp
4) Report Number: Report 269 (AD-365 382)
5) Date: September 1965
6) Classification: Secret
7) Project Number: Subproject SF-011-01-01, Task 2369 (Bureau of Ships)
8) Abstract: This investigation was made to satisfy the need for information concerning the effects of navigation, command and control capability on costs and effectiveness in operations requiring mine countermeasures. Information was developed from a specific operation and simulation approach and from more general approaches.
9) Descriptors: Amphibious operation, command and control, communication, cost, cost effectiveness, mine, mine countermeasures, Monte Carlo method, navigation, radar, radio sensor

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Mine Countermeasures, Command and Control, and Navigation
3) Applicable Situations:
   3.1) Type: Evaluation of navigation and command and control system capabilities in countering minefields and getting traffic through
      3.1.1) MOE's Selected:
         (a) Effectiveness of the navigation a command and control system, which is defined um (over all the objective parameters) o uct of the relative value of objective para mes the

value of the system in meeting these objectives. The objective parameters considered are:

(1) rate of countermeasures
(2) traffic losses
(3) reliability
(4) preparation requirements
(5) logistic support
(6) jamming resistance
(7) personnel requirements
(8) countermeasures craft losses
(9) equipment losses
(10) life losses
(11) system portability
(12) analysis capability
(13) fall back capability
(14) space and weight requirements
(15) monitoring operations
(16) adequate records
(17) complexity
(18) detectability

Limitations And Assumptions:

(1) This measure assumes that the 18 objective parameters adequately measure system effectiveness.

(2) This measure is structured from the desire to determine the value of multidimensional objectives and alternatives in terms that are comparable. Relative weighting and conversion to a composite dimension is the only known method of providing comparability in such cases. Although relative weighting involves subjective judgement which weakens any analysis,

the technique can serve to present the overview considerations and present the choice of capability in perhaps its truest light. The procedure provides an organized method of trading capabilities and selecting the most valuable combination. The method is not considered to be unquestionable or highly technical, but a practical approach.

(b) Cost of obtaining a specified level of minefield clearance within a given time. By cost is meant the total force costs which includes the procurement of the countermeasures craft and equipment, countermeasures craft and equipment losses during the operation, and amphibious ship losses.

(c) Cost-effectiveness index, which is defined as the ratio of effectiveness [as defined in (a)] to cost [as defined in (b)]

(d) Average cost reduction per operation per yard of standard deviation reduction in navigation error

(e) Coverage rates for specified standard deviation of navigation error

(f) Percent clearance actually achieved

3.2) Type: Evaluation of minesweeping equipment

3.2.1) MOE's Selected:

(a) Characteristic actuation width

(b) Nominal effective range of sweep

(c) Characteristic actuation probability

(d) Sweeper actuation width

(e) Probability of sweeper actuation

(f) Damage probability

3.3) Type: Evaluation of mine hunting equipment

3.3.1) MOE's Selected:

(a) Characteristic moored detection width

(b) Moored detection probability

(c) Characteristic influence detection/classification width

(d) Influence detection/classification probability

(e) Ship loss width to moored mines

(f) Probability of ship loss to moored mines

(g) Ship loss width to acoustic mines

(h) Probability of ship loss to acoustic mines

3.4) Type: Evaluation of mine neutralization equipment

3.4.1) MOE's Selected:

(a) Single pass probability that a neutralization charge is placed within kill radius of a mine

(b) Time per neutralization attack

(1, 2, 10, 11)

AIRBORNE ASW, AIRBORNE AAW,
SURFACE ASW AND SURFACE AAW

MOE REVIEW NO. (1,2,10,11)-1

A. STUDY DESCRIPTION

1) Originating Activity: Office of the Chief of Naval Operations, Washington, D.C.
2) Report Title: Major Fleet Escort Force Level Study, Vols. 1-3 and Supplement on Endurance
3) Authors: M.M. Gantor, H.E. Murray, K.S. Masterson, F.S. Petersen, P.W. Nelson, C.J. Dibona, C.E. Woods, W.P. Hughes, D.S. Bloom, A.H. Cummings, J.W. Abraham and G.F. Strollo
4) Report Number: (Vol. 1: AD-383 545; Supplement: AD-583 206)
5) Date: 1967
6) Classification: Secret
7) Abstract: This study is an analysis of the surface escort force levels needed in the mid-1970's to defend basic programmed Naval Forces. The number of such basic forces was assumed as given, and the study derived the economically "efficient" number of escorts on a cost and effectiveness comparison basis. The basic method used was a marginal analysis to trade-off incremental expenditures on escorts against expenditures on the forces escorted. Although the study was conducted to provide an analytical basis for missile ship force levels, it also derived total escort force levels and provides an illustrative building program designed to achieve the desired levels.
8) Descriptors: Aircraft, amphibious operation, antiair warfare, antisubmarine warfare, bomb, carrier, convoy defense, escort ship, Monte Carlo method, naval gunfire support, submarine, surface ship, surface-to-air missile, surface-to-surface missile, survivability, torpedo, vulnerability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force, System and Subsystem
2) Function: Airborne ASW, Airborne AAW, Surface ASW and Surface AAW

3) Applicable Situations:

3.1) Type: Evaluation of fleet escort requirements

3.1.1) MOE Selected:

(a) Efficient number of escorts required, which is defined as that number which on the margin, reduces losses to the escort force by an amount equal to or greater than the cost of the escort; i.e., the last escort provided by each escorted force must reduce losses to that force by an amount at least equal to the cost of the escort

3.2) Type: Evaluation of the effectiveness of fleet escort forces in AAW engagements

3.2.1) MOE's Selected:

(a) Number of escorts surviving at the end of the engagement

(b) Carrier survivability, which is defined as the probability that a carrier has minimum capability to launch aircraft (at least one catapult and operative assisting gear) at the end of the engagement

(c) Cumulative carrier days on line, which is defined as the number of days on line from arrival in the area to time of last attack not taking into consideration time off for replenishment

<u>Rationale For Selection</u>: This is a direct measure of air strike effectiveness given a specified air group, target complex, etc.

(d) Total effective carrier days on line, which is defined as the task group total days on line from arrival in area to the end of the war taking into account all time off the line

(e) Pace of operations (sorties/day, targets killed/day or ordnance delivered/day)

Rationale For Selection: This MOE is a measure of the effect air attacks have had on the carrier's ability to conduct flight operations.

3.3) Type: Evaluation of the effectiveness of fleet escort forces in ASW engagements

3.3.1) MOE's Selected:

(a) Escort kill capacity

(b) Expected number of successful enemy submarine attacks per patrol

(c) Expected number of torpedo hits on the carrier

(d) Expected number of escort ships out of action

(e) Probability that an enemy submarine is destroyed during the engagement

3.4) Type: Evaluation of the effectiveness of naval gunfire systems

3.4.1) MOE's Selected:

(a) Live target time, which is defined as the time interval from the occurrence of a target until a weapon system has fired the expected number of rounds required to achieve the desired effects upon the target

(b) Target firing time, which is measured from the time of occurrence to the impact of the first round in fire for effect

(c) Number of targets lost during the engagement

(d) Combat ratio

Rationale For Selection: This is a measure of the enemy's potential to inflict casualties on the landing force.

3.5) Type: Evaluation of the vulnerability of escorts and escorted ships

3.5.1) MOE's Selected:

(a) Probability of a hit, given acquisition of the ship

(b) Probability of damage, given a hit

(c) Expected number of days off the line

(d) Expected number of surviving escorts after an attack

(e) Probability of the loss of an escort

(1, 5, 8, 9, 10, 21, 22)

AIRBORNE ASW, MINING, SUBMARINE ASW, SUBMARINE ATTACK, SURFACE ASW, LOGISTICS AND SHIP SUPPORT

MOE REVIEW NO. (1,5,8,9,10,21,22)-1

A. STUDY DESCRIPTION

1) Originating Activity: Office of the Chief of Naval Operations, Washington, D.C.
2) Report Title: ASW Force Level Study, Vols. I-VI
3) Date: 1969
4) Classification: Secret
5) Abstract: The ASW Force Level Study was directed to develop methods for making an economic analysis of the ASW forces required to defend naval and merchant forces in the mid 1970's and to apply the methods thus developed in order to estimate the size and composition of the "optimum" ASW Force. The study developed models and procedures for performing economic analysis in two different ways: (a) finding the least-cost combination of ASW forces and additional protected forces necessary to meet military requirements stated in terms of the numbers of each type of protected force; (b) finding the least-cost ASW force necessary to defend programmed naval forces and merchant shipping (protected forces) to the degree necessary for them to meet military requirements stated in terms of the maximum acceptable losses for each type of protected force.
6) Descriptors: Aircraft, antisubmarine warfare, availability, barrier, carrier, carrier based aircraft, classification probability, contact investigation, convoy defense, cost effectiveness, countermeasure, detection probability, escort ship, hit probability, kill probability, logistics, mining, Monte Carlo method, naval gunfire support, reliability, screen, ship support, SOSUS, submarine, submarine attack, surface ship, transitor, vulnerability

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: Force, System and Subsystem
2) Function: Airborne ASW, Mining, Submarine ASW, Submarine Attack, Surface ASW, Logistics and Ship Support

3) Applicable Situations:

3.1) Type: Determination of force expenditures needed in antisubmarine warfare

3.1.1) MOE Selected:

(a) Total cost of the protected forces and ASW forces necessary to insure that given requirements for protected forces are met

- Rationale For Selection: ASW force level requirements can be determined by finding that mix and level of ASW forces which minimize this MOE.

3.2) Type: Evaluation of submarine barrier effectiveness

3.2.1) Criterion For Success: Detection and destruction of submarine

3.2.2) MOE's Selected:

(a) Probability that an enemy submarine will survive the barrier

(b) Exchange ratio between transitors and barrier submarines

(c) Expected fraction of transitors that survive an N-line barrier of given strength

3.3) Type: Evaluation of the effectiveness of ASW screen

3.3.1) Criterion For Success: Detection and destruction of submarine

3.3.2) MOE's Selected:

(a) Probability that an enemy submarine, having reached the outer periphery of the screen, will subsequently be able to shoot at the protected force

(b) Probability that the submarine, having encountered the screen, will survive the engagement

(c) Exchange ratios between surface escorts and submarines

(d) Probability that an enemy submarine, attempting to penetrate the screen is not detected

(e) Probability that an enemy submarine, attempting to penetrate the screen, is detected but not classified

(f) Probability that an enemy submarine, attempting to penetrate the screen, is unsuccessfully attacked by the screen and unsuccessfully avoided by the escorted force

(g) Probability that an enemy submarine, attempting to penetrate the screen, is unsuccessfully attacked by the screen but successfully avoided by the escorted force

(h) Probability that an enemy submarine, attempting to penetrate the screen, is successfully attacked, i.e., killed

(i) Expected number of ships sunk in the escorted force or when the escorted force is a carrier group, the expected number of carrier hits

(j) Expected number of escorts sunk

(k) Expected number of weapons expended by surviving surface screen ships

(l) Expected number of weapons expended by that fraction of enemy submarines surviving the screen

3.4) Type: Evaluation of the effectiveness of airborne ASW in conducting SOSUS prosecution of open ocean search missions

3.4.1) MOE's Selected:

(a) Probability that an enemy submarine will survive a given period of operations (either in transit or on-station) in the area covered by the aircraft

(b) Probability that at any randomly selected instant of time a submarine in the area is being held down by aircraft

<u>Rationale For Selection</u>: This MOE measures the ability of the aircraft to prevent enemy submarines from prosecuting attacks against a protected force.

3.5) Type: Evaluation of submarine minefield performance

3.5.1) Criterion For Success: Destruction of submarine

3.5.2) MOE Selected:

(a) Probability that an enemy transitor will survive the minefield

3.6) Type: Evaluation of convoy vulnerability to submarine attacks

3.6.1) MOE's Selected:

(a) Expected number of torpedoes that strike the primary target

(b) Expected number of torpedoes that strike a chance target

(c) Probability a ship is sunk

(d) Expected number of ships damaged

(e) Expected off-line times of damaged ships

(f) Expected loss = (expected number of ships sunk) X (cost of one ship) + ((expected number of ships damaged) X (cost of one ship) X (expected repair time)÷ (length of war))

3.7) Type: Evaluation of the effectiveness of countermeasures

3.7.1) MOE's Selected:

(a) Degraded hit probability due to countermeasures

(b) Degraded detection probability due to countermeasures

3.8) Type: Evaluation of equipment readiness and/or operation

3.8.1) MOE's Selected:

(a) Equipment operational readiness (EOR), which is defined as the probability that a given system will function throughout an engagement (mission) interval of specified duration (EOR = availability X reliability)

(b) Availability, which is defined as the fraction of a specified time interval that a given system will be capable of performing the function for which it was designed

(c) Reliability, which is defined as the conditional probability that a system which is functioning

satisfactorily at a given time will continue to function throughout a specified interval of time

3.9) Type: Determination of logistics support requirements

3.9.1) MOE's Selected:

(a) Number of replenishment ships required in each underway replenishment group

(b) Total number of underway replenishment group ships required

(2, 3, 14, 17, 18, 20, 21, 23)

AIRBORNE AAW, AIRBORNE ATTACK, ELECTRONIC WARFARE, NAVAL COMMUNICATIONS, COMMAND AND CONTROL, RECONNAISSANCE/ INTELLIGENCE, LOGISTICS AND SPECIAL WARFARE

A. STUDY DESCRIPTION

1) Originating Activity: Lockheed Missiles & Space Company, Sunnyvale, California
2) Report Title: Capability Measures for System Effectiveness
3) Author: A. Chop
4) Report Number: LMSC-D053773 (AD-892 863)
5) Date: February 1972
6) Classification: Unclassified
7) Contract: F30602-70-C-0197 (Rome Air Development Center)
8) Abstract: Consolidated information is presented pertinent to the definition and evaluation of capability measures for use in the analysis of system effectiveness. The measures have general applicability to the spectrum of current and future Air Force systems and missions. Two representative measures are described in detail for each of 14 specific types of strategic, tactical, and defense missions. Each description contains an expansion of the capability measures to lower level system component measures where appropriate, and includes the basic technical relationships for evaluation of the measures as a function of critical performance parameters of associated systems. Additionally, a functional flow characterizing the typical mission involved and a capability evaluation logic are summarized for each mission. A technical overview of capability measures in general is also delineated, to include a compendium of applicable measures and the systems and missions accounted for by the measures. The overview is designed to provide technical management with a knowledgeable perspective of the basic concepts of capability measures, and with guidance on the principal considerations to be addressed in their formulation and evaluation. Specific classes of evaluation techniques have direct application to the evaluation of capability measures.

These are also detailed. This information, in conjunction with the detailed description of each measure, is intended to guide the technical specialists responsible for the innovative adaption of the presented information.

9) Descriptors: Airborne attack, aircraft, air superiority, antiair warfare, close air support, command and control, communications, counterguerrilla warfare, detection, electronic warfare, intelligence, kill, message traffic, reconnaissance, sensor, supply

B. EFFECTIVENESS MEASUREMENT

1) Evaluation Level: System and Subsystem
2) Function: Airborne AAW, Airborne Attack, Electronic Warfare, Naval Communications, Command and Control, Reconnaissance/Intelligence, Logistics and Special Warfare
3) Applicable Situations:
   3.1) Type: Evaluation of missile attack on a ground target
      3.1.1) Criterion For Success: Destruction of target
      3.1.2) MOE's Selected:
         (a) Probability of killing k targets with n missiles
         (b) Expected fraction of k targets killed with n missiles
         (c) Expected fraction of a target killed within a given time
         (d) Probability of target kill with one missile
         (e) Expected fraction of a target killed with one missile
   3.2) Type: Evaluation of aircraft attack on a ground target
      3.2.1) Criterion For Success: Destruction of target
      3.2.2) MOE's Selected:
         (a) Single target kill probability
         (b) Number of weapons required by x bombers to kill k targets in one pass
         (c) Expected fraction of k assigned targets killed per sortie without loss of aircraft

3.3) Type: Evaluation of escort aircraft performance

3.3.1) Criterion For Success: Successful defense of escort aircraft

3.3.2) MOE's Selected:

(a) Probability of kill of an attacking enemy aircraft by an escort aircraft

(b) Expected attrition index of enemy attacking aircraft without loss of an escorted aircraft

(c) Expected fraction of enemy penetrations prevented without loss of an escort or escorted aircraft

(d) Probability of successful escort defense against the enemy attack

3.4) Type: Evaluation of capability to suppress enemy penetration by aircraft, missile or space vehicle

3.4.1) Criterion For Success: Suppression of aircraft penetration

3.4.2) MOE's Selected:

(a) Probability of preventing a single penetration

(b) Expected fraction of enemy penetrations prevented, given n engagements

(c) Attrition ratio of hostile to friendly force, given x penetrations

3.5) Type: Evaluation of detection and tracking capability against airborne targets

3.5.1) Criterion For Success: Detection and tracking of target

3.5.2) MOE's Selected:

(a) Probability of detection and tracking within a specified response time

(b) Expected fraction of successful real detections and trackings per n opportunities

3.6) Type: Evaluation of the ability to perform command and control statusing and data correlation

3.6.1) MOE's Selected:

(a) Probability of successful identification within a given time

(b) Expected fraction of real identifications out of n opportunities within a given time

(c) Probability of displaying and maintaining current status on n identification/correlation variables

3.7) Type: Evaluation of communication system performance

3.7.1) MOE's Selected:

(a) Probability of a single intelligible message being transmitted and received in a given time

(b) Expected fraction of intelligible messages which can be transmitted and received in a given time

(c) Number of intelligible messages which can be transmitted and received within a specified time interval

3.8) Type: Evaluation of aircraft performance in an air superiority mission

3.8.1) MOE's Selected:

(a) Probability of a single successful air superiority sortie

(b) Relative attrition ratio of friendly and hostile aircraft in n air-to-air engagements of y duration, given specific mission ranges of engagements

3.9) Type: Evaluation of aircraft performance in a close air support mission

3.9.1) MOE's Selected:

(a) Probability of a single successful close air support sortie

(b) Expected fraction of k targets killed or contained in n sorties without loss of aircraft, given a specific loiter time

(c) Expected fraction of a target killed per close air support sortie

3.10) Type: Evaluation of aircraft performance in a counterinsurgency role

3.10.1) MOE's Selected:

(a) Probability of a single successful counterinsurgency sortie

(b) Fraction of incidents prevented

3.11) Type: Evaluation of reconnaissance system performance

3.11.1) MOE's Selected:

(a) Probability of obtaining and transmitting x specified items of intelligence on n passes, given a specific resolution of data

(b) Expected fraction of x items of intelligence obtained in a specified time duration t, given a specific resolution of data

3.12) Type: Evaluation of the capability to neutralize enemy communications

3.12.1) MOE's Selected:

(a) Probability of x percent of hostile communications impairment for a specified time duration t

(b) Expected fraction of hostile communications impaired for a specified time duration t, given n opportunities

3.13) Type: Evaluation of sensor performance in electronic warfare

3.13.1) MOE's Selected:

(a) Probability that k of n deployed sensors will provide a defined set of correlatable signals for a specified time period

(b) Expected fraction of correlatable signals receivable from n sensors

(c) Probability of obtaining a defined set of correlatable signals from a sensor, given a specific sensor discrimination efficiency, radiated power, security, and spurious signal rejection

3.14) Type: Evaluation of the performance in air movement and air drops of troops, supplies, and equipment

3.14.1) MOE's Selected:

(a) Expected tonnage of material moved by an airlift aircraft per mission of specified range

(b) Expected tonnage fraction of material successfully forwarded in n sorties within a specified time

(c) Probability of a successful movement of material upon a single demand, given a minimum tonnage and maximum forwarding time