Final Summary Report

for the

U.S. Army Materiel Systems Analysis Agency

Aberdeen Proving Ground, Maryland 21005

under contract

"Research Support on Method-Model Development"

DAAD05-76-C-0739

conducted by

The School of Industrial and Systems Engineering

Georgia Institute of Technology

Atlanta, Georgia 30332

Harrison M. Wadsworth, Jr.

Douglas C. Montgomery

Principal Investigators

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I. Nature of the Research Program

A. Background: The School of Industrial and Systems Engineering of the Georgia Institute of Technology began to offer Operations Research/ Systems Analysis courses at the graduate level in the 1950's. A small number of officers and civilians from the Department of Defense who were pursuing graduate degrees in established areas enrolled in these courses. In 1969 the U.S. Army developed a core curriculum for a formal graduate program in OR/SA, and selected Georgia Tech as one of the two civilian institutions for concentrated use in meeting Army graduate educational needs in this area. In 1972, the School was authorized to award a graduate degree in operations research (MSOR). A number of joint reviews have been made with the goal of improving the Army OR/SA program requirements. The latest was held in November, 1976. Sixteen Army personnel entered the program in 1969, and by 1973, 35 students were in residence with approximately 20 graduating a year. At present approximately 20 officers are in residence with a forecasted level of approximately 20 in residence and an output of 10 per year.

B. The Theses Problem: For almost all Master's degree candidates, the identification and definition of a thesis topic of interest both to the student and to his research advisor requires a disproportionate amount of time, when compared with the course requirements or actual thesis research. One of the important objectives to be realized in this program is the development of readily available research topics relevant to Army needs and objectives and potentially interesting to Army personnel, and of competent, involved research advisors. These availabilities are critical if the Army personnel are to complete an acceptable thesis within the time constraint of their tenure in the program. A review of theses by Army officers prior to 1974 indicated a small percentage directly related to Army needs and

problem areas. The situation was highlighted by Dr. Wilbur Payne, Deputy Under Sec. of the Army in October, 1973 in a letter to Georgia Tech commenting on the revised curriculum programs when he stated:

> "I was very interested in the comments you received from the officer students in response to your Proposal Review memorandum. Of particular interest were their remarks concerning the lack of adequate communication between the Army and students, and the resulting scarcity of appropriate military related thesis topics. This has for some time also been a concern of mine. I believe that something can be done to improve this situation, and would be delighted to work with the Institute toward that goal."

C. Theses Support Program: During the Fall of 1973 and Spring of 1974 a number of conferences and seminars were held between the Georgia Tech faculty and Army agencies to improve the relevancy of thesis research. In June, 1974 the Army Materiel Systems Analysis Agency contracted to support three officers, and in the Fall of 1974 the U.S. Army Operational Test and Evaluation Agency agreed to sponsor seven officers under two separate contracts. These contracts support the officer students by providing office space, leased computer terminals, and other logistic support at Tech. The contracts have also covered approximately 1/4 time salaries, overhead and limited travel for some faculty members for efforts beyond what would otherwise be required for their faculty duties. In addition to contract support, the sponsoring agency provides travel support and data sources for officer students. Actual thesis topics are developed between the student, the faculty and the sponsor to assure Army relevance, academic quality and to insure that they are within the individual officer's capabilities. Both of these contracts have since been renewed for another year. This report culminates the end of the second year of the AMSAA contract.

D. General Method of Approach: Literature search and problem definition in the two areas above began in the summer of 1974. Faculty members met frequently with individual students and began to collect background material from OTEA, USAMSAA, Command and General Staff College, the Army Logistic Management Agency, and other Army agencies as well as from the Georgia Tech Library. Frequent seminars and conferences between all the students and faculty were held to promote development of individual thesis topics. This activity has continued through 1976.

E. Scope of Report: This report provides a final summary for work done for the U.S. Army Materiel Systems Analysis Agency under contract DAAD05-76-0739 subject "Research Support on Method-Model Development" awarded for 12 months of theses support during the period 5 January 1976 to 4 January 1977.

II. Results

A. Under the provisions of subparagraph A, B, and C of Section F.3 of the second year contract, three reports were submitted to the sponsor in December, 1976 (Incls.)

B. In addition, a final report giving the results of research under the task cited in Section F.3 of contract number DAAD05-74-C-0777 is also enclosed. Work under this first year contract was previously reported except for the referenced task.

Summaries of the four reports described above are attached.

U.S. ARMY MATERIEL SYSTEMS ANALYSIS AGENCY

RESEARCH SUPPORT ON METHOD-MODEL DEVELOPMENT

DAAD05-76-C-0739

AN APPLICATION OF MULTIVARIATE STATISTICAL TECHNIQUES TO THE ANALYSIS OF THE OPERATIONAL EFFECTIVNESS OF A MILITARY FORCE

Harrison M. Wadsworth, Jr.
Douglas C. Montgomery
Project Directors

James T. Baird, Capt.
Principal Investigator

Georgia Institute of Technology
December 1976

SUMMARY

This research addresses the problem of determining the contribution of operational mobility to the operational effectiveness of a military force and the contribution of differences in operational mobility to differences in operational effectiveness for forces employing competing land combat vehicle systems. Two definitions of the operational mobility of a force are proposed, along with suggested methods for their representation as quantifiable measures of effectiveness (MOE). The first definition is based on a measure of relative momentum between two forces engaged in combat, while the second is based on relative measures of critical operational performance characteristics of particular vehicles employed in combatant forces.

A general methodology, based on classical, well-documented, multivariate statistical procedures, is then developed that enables determination of significant differences between the operational effectiveness of forces employing competing material systems and relative contributions of individual MOE, to include any measure of operational mobility, to a force's operational effectiveness.

The methodology includes an investigation of the multivariate normality of a set of MOE obtained from hypothesized replications of a stochastic combat model by utilizing two previously developed tests for multivariate normality. One test is based on order statistics, while the other utilizes a non-linear transformation procedure that induces multi-

variate normality into a data set. An approximate procedure was also developed to facilitate translation of inferences drawn after non-linear transformation to inferences on original variables.

The methodology is applied to two hypothetical example problems to illustrate the fact that either definition of operational mobility is conformable to analysis. Statistical analyses in each example problem are limited to the two sample case with equal sample sizes, unknown covariance matrices, and assumed independence between data sets.

U.S. ARMY MATERIEL SYSTEMS ANALYSIS AGENCY

RESEARCH SUPPORT ON METHOD MODEL-DEVELOPMENT

DAAD05-76-C-0739

AN APPLICATION OF TIME-STEP SIMULATION TO ESTIMATE AIR DEFENSE SITE SURVIVABILITY

Harrison M. Wadsworth, Jr.
Douglas C. Montgomery
Project Directors

James M. Rowan III, Capt.
Principal Investigator

Georgia Institute of Technology
December 1976

SUMMARY

This research presents a time-step simulation methodology that rapidly generates accurate estimates of air defense site survivability when an integrated missile defense is attacked by more than one enemy aircraft. A comparison and brief review of the major simulations used to study air-to-ground warfare is included.

The simulation presented, called AIRDEF, allows the user to specify the number of estimates to be generated, the number of battles to be executed in the generation of each estimate, and the size of the time-step to be used. The aircraft are modeled in terms of their position, speed, number, and engagement range of ground targets; the air defense sites are modeled in terms of their number, position, acquisition range, tracking and firing minimum times, target acquisition capability, missile speed, and missile launch and kill probabilities. The user inputs the aircraft and air defense parameters once for initialization. The demonstration of AIRDEF includes a typical printout from a representative time step, a complete execution of the simulation, and the results of an example run of simulation experiments.

The methodology and simulation presented were developed for use by analysts studying air-to-ground combat. Anticipating that many estimates of site survivability will be needed by tactical commanders over a narrow range of attack aircraft parameters, a methodology for efficiently summarizing these estimates in a simple regression equation is also presented and demonstrated. The equation for tactical use is obtained by generating

three estimates for each cell of a 3^4 experiment which varies aircraft number, speed, attack range, and electronic counter-measure capability, using ANOVA and regression techniques to formulate a predictive equation valid for the conditions of interest.

The research concludes that AIRDEF and the associated methodology procedures accurate and useful estimates of air defense site survivabilities. It also provides evidence that time-step simulation may be more fruitful than next-event simulation in further studies of the same type.

U.S. ARMY MATERIEL SYSTEMS ANALYSIS AGENCY

RESEARCH SUPPORT ON METHOD-MODEL DEVELOPMENT

DAAD05-76-C-0739

A MATHEMATICAL PREDICTIVE MODEL OF ARM STRENGTH

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Douglas C. Montgomery
Project Directors

Robert S. Lower, Capt.
Principal Investigaror

Georgia Institute of Technology
December 1976

SUMMARY

Arm strength studies have typically been done for arm positions in the frontal and sagittal plane. Little is known concerning arm strength behavior in three dimensions or concerning strength variation in the transverse plane. This research consists of four phases:

1. Design of an arm strength testing apparatus,
2. Collection and statistical analysis of preliminary data on three dimensional arm strength behavior,
3. Examination of transverse plane strength and determination of possible mathematical forms for a predictive equation, and
4. Final development of a useful predictive model for arm strength in the transverse plane.

Two separate studies were conducted, called Study I and Study II. In Study I, tests were made on 18 handle locations in representative portions of the reach sphere, each location uniquely determined by a vertical plane passing through the center of the chair (sagittal, frontal, or 45 degree planes) and a vertical distance or height above the seat level (0, 20, or 40 inches). Each of the 18 handle locations were tested at three distances from the body (near, mid-range, far), in three forearm rotations (pronation, mid-position, supination), and in six directions of force (left, right, up, down, push, pull). A total of 972 tests were evaluated for one subject.

Strength was found to be greatest 20 inches above the chair seat, decreasing as the hand is raised or lowered from that level. The greatest

forces were found generally to be exerted in the right front quadrant of the reach sphere, with lowest forces exerted with the hand directly behind the head. All strength values were greatly dependent upon the direction of force exertion.

Study II consisted of an analysis of push forces exerted in the 20 inch transverse plane, forearm in mid-position. In the transverse plane, strength varies parabolically with the distance of the hand grip from the SRP. A computationally simple mathematical equation that will predict arm strength as a function of spacial coordinates of the hand was derived.

U.S. ARMY MATERIEL SYSTEMS ANALYSIS AGENCY

RESEARCH SUPPORT IN OPERATIONS RESEARCH/SYSTEMS

ANALYSIS APPLICATIONS TO ARMY NEEDS AND OBJECTIVES

DAAD05-74-C-0777

OPTIMUM ASSIGNMENT AND SCHEDULING OF ARTILLERY UNITS TO TARGETS

Leslie G. Callahan, Jr.
Project Director

Everett D. Lucas, Capt.
Principal Investigator

Georgia Institute of Technology
October 1976

SUMMARY

This research is concerned with a particular type of assignment and scheduling problem, one involving optimizing the assignment of artillery units, by their capabilities and location relative to a particular target, to fire on certain enemy targets according to a schedule which orders the firing in priority of the importance of the targets. The method assumes that the target analyst will be able to determine the type of artillery unit to fire on a given target, thus enabling him to determine the number of units and number of volleys required to achieve the desired results. Also, using a given weighting scheme, the analyst can derive comparative weights for the targets which, when inserted into the assignment problem would insure optimum allocation of artillery units. This allows the scheduling of those same targets in a manner such that they would be scheduled at the earliest possible time.

Although developed to schedule 155 mm and 8" artillery units, the problem formulation lends itself to change to allow for other types of field artillery firing units. Further, the formulation is such that it can simply be converted to a computerized format capably handled by most computers now in use in the United States Army. This computerization would greatly enhance the target analysis requirement in a combat situation. Its applicability is not limited to the scheduling phase, but for all phases of fire planning.