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METHODOLOGY FOR RELATING ENGINEER PROCESSES TO BATTLEFIELD  
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METHODOLOGY FOR  
RELATING ENGINEER PROCESSES  
TO BATTLEFIELD EFFECTIVENESS  
(MEREPROBE) •

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FINAL REPORT, ON  
Delivery Order 0134

Contract No. DAAG29-76-D-~~0100~~

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901 North Washington Street  
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12 32p.

11  
31 January 1977

1473

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METHODOLOGY FOR RELATING ENGINEER PROCESSES  
TO BATTLEFIELD EFFECTIVENESS (MEREPROBE)

INTRODUCTION

Background

This report is the final product to be delivered under Contract No. D.O. 0134 between Battelle Columbus Laboratories (BCL) and Chase, Rosen & Wallace, Inc. (CRW). The objective of this effort and the specific tasks to be performed were described in the contract document as follows:

"OBJECTIVES: The objective of this requirement is to obtain an independent evaluation of a methodology developed by the US Army Engineer School (USAES) in-house to determine the impact of various levels of Engineer proficiency in the performance of Engineer combat support tasks on the overall combat effectiveness of a force in battle. Additionally, a methodology is needed to address this same problem at a lower level of resolution than that used in the USAES methodology.

SPECIFIC TASKS:

- a. Review the methodology developed by the USAES.
- b. Review related documents and research papers pertaining to the requirement.
- c. Identify strengths and weaknesses of the USAES developed methodology.
- d. Propose methodology for addressing similar type problems but at a lower level of resolution, i.e., Corps/Theater."

A preliminary report on this project contained a brief evaluation of the methodology and outlined an approach to be followed in accomplishing the indicated tasks.

## Summary

The USAES methodology discussed in this report is concerned with two major problems. The first of these is to relate the proficiency with which combat engineer units perform their tasks to the level and type of training they have had, and the second is to relate the combat effectiveness of a maneuver force to the performance of engineer tasks in support of such a force. A large fraction of the total analytical effort devoted to evaluation of military operations is concerned with combat or maneuver forces, thus a wide variety of games, computer simulations and analytical techniques for assessing the effectiveness of maneuver units at all levels of resolution from individual tank or soldier to division, corps or theater exists. Many of these techniques take into account supporting elements of various kinds but they are not primarily designed nor necessarily adaptable to the evaluation of support forces.

Most of the effort which has been devoted to the evaluation of supporting elements has focused on logistical support, thus the USAES effort to develop approaches to measuring the effectiveness of the support provided to maneuver units by the combat engineers is focused on an area which is not extensively covered in current evaluation capabilities. The second problem, namely investigation of the impact of training on engineer proficiency, is even less well covered by currently available techniques. Accordingly the USAES effort clearly constitutes a new approach to a significant problem.

At the beginning of this study reported here, the USAES methodology consisted essentially of that described in Reference c. During the course of this effort, the methodology was significantly extended and generalized. The expanded methodology is described in this report; much of the work connected with the expansion was done by USAES personnel.

The remainder of this report is devoted to a description of the expanded USAES methodology and to a discussion of it in accordance with the scope of work for this project. Conclusions and recommendations resulting from this effort are also presented.

The CRW effort was accomplished by Mr. Martin N. Chase. Mr. Mark Pell of USAES was responsible for much of the generalization of the methodology. Finally, the contractual support provided by the Battelle Columbus Laboratories is acknowledged.

#### References

The following publications, provided by USAES, were reviewed during the course of this study:

- a. Correspondence between CG, TRADOC and CG, USAES, subject "Analysis of Training Effectiveness", February 1975.

- b. "Measuring Obstacle Effectiveness", Engineer Studies Group, March, 1975.
- c. "Impact of Engineer Proficiency on Combat Effectiveness of a Force" USAES, 1 September 1975.
- d. "Analyzing Training Effectiveness" TRADOC PAM 71-8, 1 December 1975.
- e. "Evaluation of the Tactical Effectiveness of Barrier Obstacles", Vol. 1, Braddock, Dunn & McDonald, Inc. 15 September 1974.

In addition, to illustrate the relationship between Engineer-type tasks and battle outcomes, reference is made to:

- f. "History of the Second World War" Liddell-Hart, Putnam & Sons, 1970.

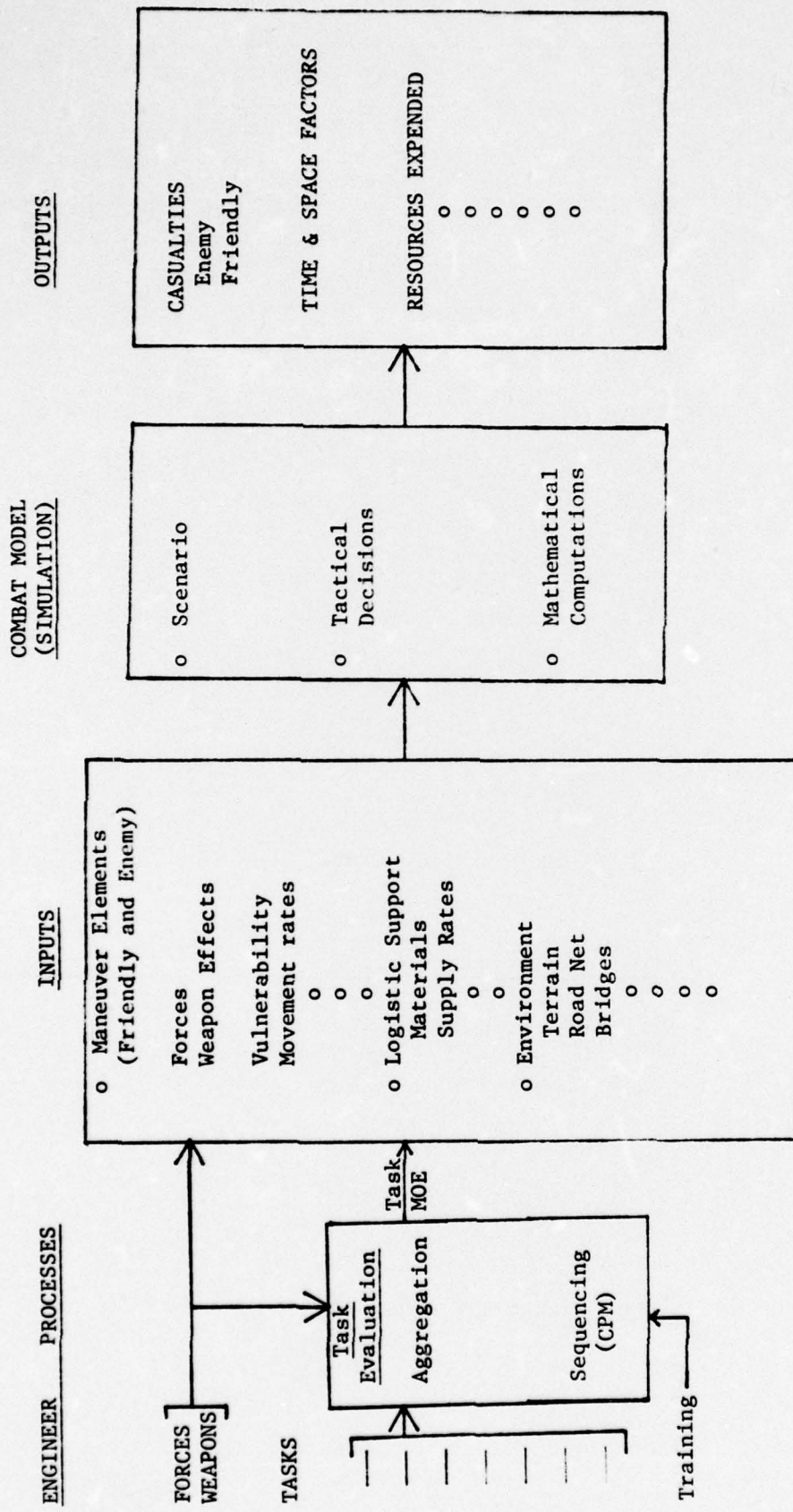
## DESCRIPTION OF THE USAES METHODOLOGY

The USAES methodology for relating Engineer Processes to Battlefield Effectiveness (MEREPROBE), as generalized during the course of the study reported here, is shown schematically in Figure 1. The basic premise of this methodology is that the ultimate measure of effectiveness of any engineer activity is the resulting increase in combat effectiveness of the supported force. Accordingly, the combat model, which is central to the methodology, must meet several criteria:

- o It must be suitable for detailed evaluations of the supported force,
- o It must accept as inputs parameters that describe the results of Engineer activities,
- o Outputs of the model must be sensitive to reasonable variations in such parameters.

The remainder of this section of the report is devoted to a discussion of ways in which the performance of Engineer tasks can be related to the input parameters for such a combat model.

As the first step in this discussion, it is necessary to correlate descriptions of Engineer activities at several levels of abstraction. At the highest level are the Roles of the Combat Engineers, as derived from FM 5-100, "Engineer Combat Operations":



METHODOLOGY FOR RELATING ENGINEER PROCESSES TO BATTLEFIELD EFFECTIVENESS (MEREPROBE)

Figure 1

- o To enhance friendly mobility
- o To impede enemy mobility
- o To provide protective shelters
- o To fight as infantry
- o To reduce enemy protection.

The functional statements presented in FM 100-5, "Operations" are more specific:

- "o As tanks move forward, combat engineers support and assist by:
  - . Breaching and clearing minefields, obstacles, barriers and fortified positions,
  - . Assisting in river crossing operations,
  - . Assisting the forward movement of fuel and ammunition,
  - . Laying mines and creating obstacles on the flanks of the attack,
  - . Operating as infantry, if required.
- o Combat Engineers support and assist the defense by:
  - . Creating obstacles and minefields to reinforce the defensive advantages of the terrain
  - . Opening and closing lateral tactical routes
  - . Blocking avenues of approach
  - . Stopping enemy forces in the fields of fire of defending weapons
  - . Undertaking combat construction to harden critical command, control and logistic elements
  - . Operating as infantry, if required."

Finally, the most specific descriptions considered in this report are the listings in the ARTEP Master Task Inventory. This listing is used because it is complete, although ARTEP 5-145, for example, contains more detail on some of the tasks. It is also noted that the USAES document "Impact of Engineer Proficiency on Combat Effectiveness of a Force", which describes one example of the methodology under discussion here, uses task nomenclature that differs from the ARTEP list.

Because the ARTEP is the basis for training activities, and, hence, for combat activities, it appears highly desirable to use its nomenclature in evaluating the effectiveness of engineer activities. Moreover, it is essential that effectiveness be evaluated in the complete context of the roles of the Combat Engineers. Accordingly, it is necessary to delineate the way in which each task in the list contributes to one or more of the roles.

An abbreviated illustration of the way in which the tasks contribute to the functions described in FM 100-5 and the latter, in turn, contribute to the roles is presented in Figure 2. It is apparent from this illustration that the FM 100-5 function statements do not contribute to an understanding of the way in which tasks support roles. Accordingly, the methodology discussed here is based on relating the ARTEP tasks directly to the combat roles.

<u>Role</u>	<u>FM 100-5</u>	<u>ARTEP Task</u>
Enhance Friendly Mobility	Breach and clear minefields, etc.	7-3 Breach obstacles with explosives
		7-8 Employ the CEV
	Assist in river-crossing operations	10-13 Construct M4T6 raft 10-31 Construct a MAB
Impede Enemy Mobility	Create obstacles and minefields	6-20 Construct road blocks
	Block avenues of approach	6-43 Install barrier minefield 6-16 Disable bridges
		6-17 Crater roads
Provide Protective Shelters	Undertake construction to harden critical elements	6-22 Construct command posts 6-25 Construct vehicle defilades
Fight as Infantry	Operate as infantry	11-5 Conduct deliberate attack 11-8 Defend choke point

Figure 2

ENGINEER TASK DESCRIPTIONS

Once this approach was established it became clear that there are at least three distinct categories of ARTEP tasks. For the purposes of this report, the three categories are as follows:

End Item Tasks

Tasks that contribute directly to one or more of the roles, e.g. 10-31: Construct a MAB.

Specific Support Tasks

Tasks whose sole purpose is to support a single end-item task, e.g. 10-29: Operate MAB Transporter

Overall Support Tasks

Tasks that support several end-item tasks or the engineer operation as a whole, e.g.,

10-1: Reconnoiter crossing sites

1-1: Utilize staff planning procedures

1-9: Provide liaison to supported elements.

In a thorough study of the effectiveness of a specific Engineer action, it would be desirable to investigate the relationships among the tasks, in detail, using these or similar categories. An appropriate way to do this would be through the use of critical path methods (CPM) as illustrated on pages 11 and 12 of ARTEP 5-145. Such an analysis could show the way in which the level of proficiency in a supporting task affects the performance of an end-item task.

The final phase of this part of the methodology is to select parameters through which the effect of performing each task can be measured. These parameters play a dual role in the overall evaluation, in that they serve both as measures of effectiveness (MOE) for the individual tasks and as inputs for the models used to measure combat effectiveness.

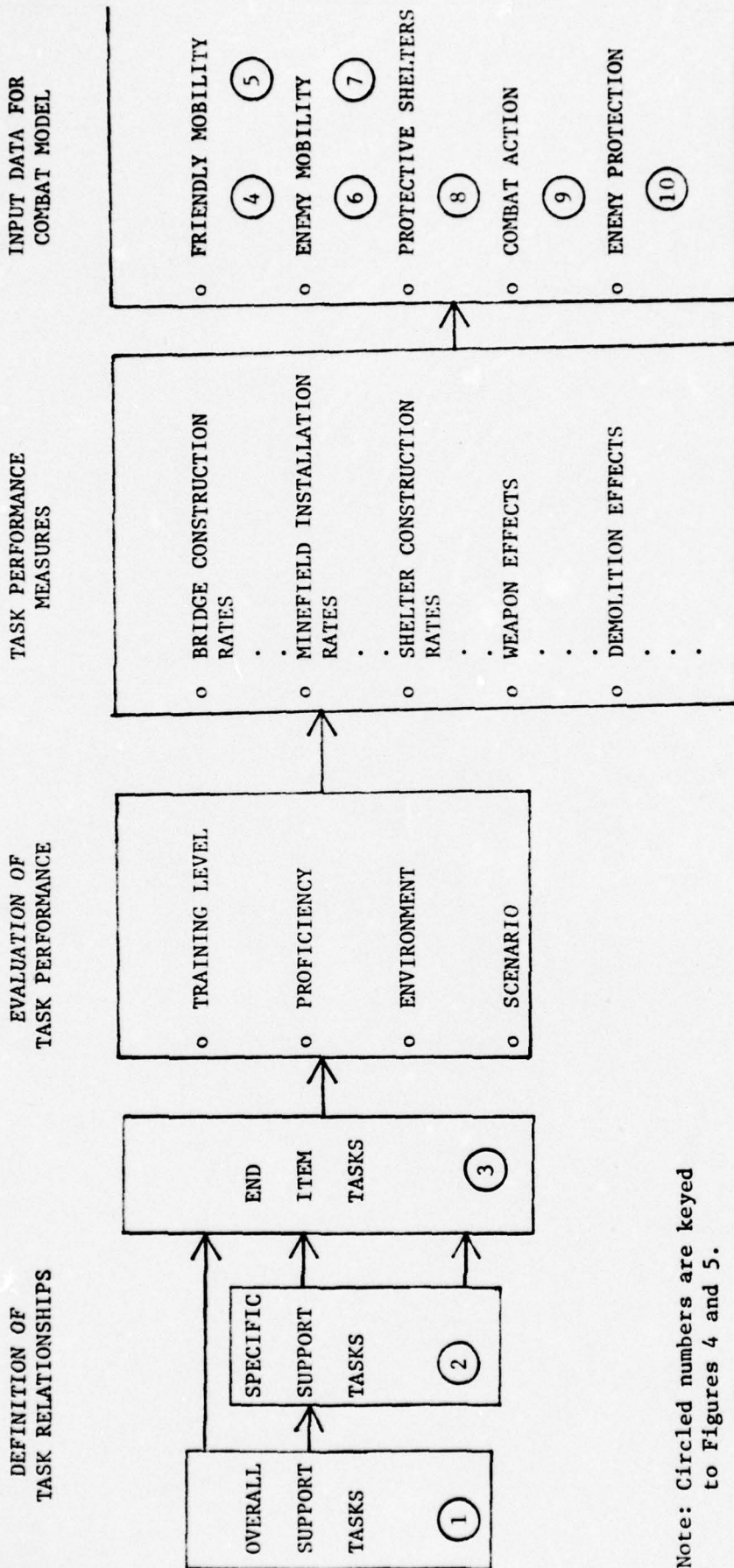
One way of defining such parameters is to start with the roles of the Combat Engineers. The remainder of this report is based on the use of the parameters shown in the following list:

<u>Role</u>	<u>Parameters</u>
Enhance Friendly Mobility	. Movement rates of friendly maneuver units . Capacity of friendly routes (tons or vehicles or troops per hour per day)
Impede Enemy Mobility	. Movement rates of enemy maneuver unit . Capacity of enemy routes
Provide Protective Shelters	. $P_k$ of enemy weapons against friendly targets . Levels of exposure
Fight as Infantry	. Firepower potential scores
Reduce Enemy Protection	. $P_k$ of friendly weapons against enemy targets . Levels of exposure

The way in which these parameters relate to the evaluation methodology under discussion can be illustrated by a more detailed view of the left side of Figure 1, as presented in Figure 3. Several comments can be made about Figure 3. In the first place, it is not possible to give a simple general description of the relationship among tasks of the three categories shown, since some end item tasks may have several specific support tasks while others may have none. Thus, in any evaluation of Engineer effectiveness, it will be necessary to specify all of the tasks involved, delineate the specific way in which they are interrelated, e.g. by the use of CPM, as suggested earlier.

In the second place, the measures of effectiveness for each task are of two kinds; the intrinsic measures appropriate to the task itself, which measure engineer performance, and the higher-level measures describing the force effectiveness of maneuver units supported by the task. Thus, an intrinsic measure for construction of a minefield might be numbers of mines laid per hour, while a higher-level measure would be the overall effectiveness of the defensive position of which the minefield is a part.

Finally, three aspects of the aggregation process must be distinguished; the aggregation implicit in the relationship of supporting tasks to end-item tasks, the additive



Note: Circled numbers are keyed to Figures 4 and 5.

Figure 3

DEVELOPMENT OF INPUT DATA

effect of several units independently performing the same task and the complex case of a large unit whose components are performing a variety of different end-item tasks.

The circled numbers in Figure 3 are keyed to the numbers in Figures 4 and 5, which provide a more detailed view of portions of the task spectrum. In Figure 4, the categorization of some of the tasks in ARTEP section 10, conduct float bridging operations, is shown. Figure 5 is a sample of the format used to display the relationship of the end-item tasks to the combat roles, using the parameters listed previously.

USAES has applied this approach to the tasks in the ARTEP master inventory, with the results presented in Figure 6. It is emphasized that no attempt was made to list quantitative values for the parameters, both because that step requires a complete specification of the tactical situation and because of the importance of showing the relationships involved, without the obscuring effect of large quantities of numerical data.

OVERALL SUPPORTING TASKS

- 10-1 Reconnoiter crossing sites
- 10-2 Plan bridge and raft construction operations
- 10-7 Install bridge protective devices
- 10-8 Perform recovery operations

SPECIFIC SUPPORTING TASKS - MAB

- 10-29 Operate MAB transporter on land
- 10-32 Replace damaged bay in MAB raft or bridge
- 10-33 Disassemble and disperse MAB raft or bridge
- 10-34 Interchange MAB super-structure

END ITEM TASKS

- 10-3 Prepare crossing sites
- 10-4 Construct temporary ford sites
- 10-5 Prepare swim sites
- 10-13 Construct M4T6 raft
- 10-22 Prepare crossing sites for NITEOPS
- 10-23 Construct light tactical raft
- 10-27 Construct flying ferry
- 10-30 Construct and operate MAB rafts
- 10-31 Construct a MAB bridge

1

2

3

Figure 4

EXAMPLE OF ARTEP TASK RELATIONSHIPS

FROM SECTION 10. CONDUCT FLOAT BRIDGING OPERATIONS

ARTEP TASK NO.	ROLES	ENHANCE FRIENDLY MOBILITY	IMPEDE ENEMY MOBILITY	PROVIDE PROTECTIVE SHELTERS	FIGHT AS INFANTRY	REDUCE ENEMY PROTECTION
		MEASURES OF EFFECTIVENESS	MOVEMENT RATES/FRIENDLY MANEUVER UNITS FRIENDLY ROUTE CAPACITY/ TONS/VEHICLES/PEOPLE PER HOUR/DAY	MOVEMENT RATES/ENEMY MANEUVER UNITS ENEMY ROUTE CAPACITY/ TONS/VEHICLES/PEOPLE PER HOUR/DAY	PK OF ENEMY WEAPONS VERSUS FRIENDLY TARGETS/ LEVELS OF EXPOSURE	PK OF FRIENDLY WEAPONS VERSUS ENEMY TARGETS/ LEVELS OF EXPOSURE
		(4)				
		(5)				
		(6)				
		(7)				
		(8)				
		(9)				
		(10)				
		(3)				

Figure 5  
 KEY TO DATA ELEMENTS IN TASK-ROLE  
 RELATIONSHIPS PRESENTED IN FIGURE 6



ARTEP TASK NO.	ROLES	MEASURES OF EFFECTIVENESS		ENHANCE FRIENDLY MOBILITY		IMPEDE ENEMY MOBILITY		PROVIDE PROTECTIVE SHELTERS	FIGHT AS INFANTRY	REDUCE ENEMY PROTECTION
		ARTEP 5-145 TASKS		MOVEMENT RATES/FRIENDLY FRIENDLY ROUTE CAPACITY/ TONS/VEHICLES/PEOPLE PER HOUR/DAY	MOVEMENT RATES/ENEMY ENEMY ROUTE CAPACITY/ TONS/VEHICLES/PEOPLE PER HOUR/DAY	MOVEMENT RATES/ENEMY ENEMY ROUTE CAPACITY/ TONS/VEHICLES/PEOPLE PER HOUR/DAY	MOVEMENT RATES/ENEMY ENEMY ROUTE CAPACITY/ TONS/VEHICLES/PEOPLE PER HOUR/DAY			
6-16	PROVIDE ENGINEER SUPPORT FOR BARRIER AND DEFENSIVE OPERATIONS									
6-17	Disable bridges									
6-19	Crater roads									
6-20	Construct obstacles with Engineer Equipment									
6-21	Construct expedient roadblocks									
6-23	Emplace non-explosive anti-vehicular obstacles									
6-25	Construct fighting bunkers									
6-26	Construct vehicle and track defilades									
6-28	Construct artillery emplacements									
6-35	Construct expedient boobytraps									
6-36	Install a hasty protective minefield									
6-37	Install a deliberate protective minefield									
6-43	Install a point minefield									
6-44	Install defensive/barrier minefield by standard cluster pattern									
6-45	Close lane in obstacle trace									
6-46	Install row minefield using M-57 mine planter									
6-47	Install AP mines in field layed by M-57 mine planter									
6-48	Install and record a phoney minefield									
	Prepare and detonate atomic demolitions									

Figure 6 (cont.)  
RELATIONSHIP OF ARTEP TASKS TO  
ROLES OF COMBAT ENGINEERS

ARTEP TASK NO.	ROLES	ENHANCE FRIENDLY MOBILITY		IMPEDE ENEMY MOBILITY		PROVIDE PROTECTIVE SHELTERS		FIGHT AS INFANTRY		REDUCE ENEMY PROTECTION
		MOVEMENT RATES/FRIENDLY	FRIENDLY ROUTE CAPACITY/TONS/VEHICLES/PEOPLE PER HOUR/DAY	MOVEMENT RATES/ENEMY	ENEMY ROUTE CAPACITY/TONS/VEHICLES/PEOPLE PER HOUR/DAY	Pk OF ENEMY WEAPONS VERSUS FRIENDLY TARGETS/LEVELS OF EXPOSURE	FIREPOWER POTENTIAL SCORE	Pk OF FRIENDLY WEAPONS VERSUS ENEMY TARGETS/LEVELS OF EXPOSURE		
7-	PROVIDE ENGINEER SUPPORT FOR BREACHING AND CLEARING OPERATIONS	MEASURES OF EFFECTIVENESS								
7-2	Remove obstacles w/engineer equipment	X	X							
7-3	Breach obstacles w/explosives	X	X							
7-4	Conduct route sweeps	X	X							
7-5	Conduct a hasty minefield breach	X	X							
7-7	Employ the AVLB (Armored Vehicle Launched Bridge)	X	X							
7-8	Employ the CEV (Combat Engineer Vehicle)	X	X							
7-10	Conduct deliberate breaching and clearing operations	X	X							
7-11	Assist in assault of fortified positions	X	X							
7-12	Destroy fortified positions	X	X							
7-13	Inspect and repair captured bridges	X	X							
8-	CONDUCT FIXED BRIDGING OPERATIONS	X	X							
8-4	Construct expedient bridge w/native timber	X	X							
8-5	Reinforce bridge with pier/bent	X	X							
8-6	Construct M4T6 fixed spans	X	X							
8-7	Emplace M4T6 fixed spans	X	X							
8-9	Construct Bailey bridge	X	X							
8-13	Construct steel trestle bridge using M4T6 components	X	X							
8-16	Construct three rope bridge	X	X							

Figure 6 (cont.)

RELATIONSHIP OF ARTEP TASKS TO ROLES OF COMBAT ENGINEERS

ARTEP TASK NO.	ARTEP 5-145 TASKS	ROLES		ENHANCE FRIENDLY MOBILITY		IMPEDE ENEMY MOBILITY		PROVIDE PROTECTIVE SHELTERS		FIGHT AS INFANTRY		REDUCE ENEMY PROTECTION	
		MEASURES OF EFFECTIVENESS	MOVEMENT RATES/FRIENDLY MANEUVER UNITS	FRIENDLY ROUTE CAPACITY/TONS/VEHICLES/PEOPLE PER HOUR/DAY	MOVEMENT RATES/ENEMY MANEUVER UNITS	ENEMY ROUTE CAPACITY/TONS/VEHICLES/PEOPLE	MOVEMENT RATES/ENEMY MANEUVER UNITS	FRIENDLY TARGETS/LEVELS OF EXPOSURE	FIREPOWER POTENTIAL SCORE	Pk OF FRIENDLY WEAPONS VERSUS ENEMY TARGETS/LEVELS OF EXPOSURE			
9-	PROVIDE ENGINEER SUPPORT FOR ASSAULT RIVER CROSSING		X										
9-9	Utilize expedient river crossing techniques		X										
9-10	Construct expedient rafts		X										
10-	CONDUCT FLOAT BRIDGING OPERATIONS												
10-3	Prepare crossing sites		X	X									
10-4	Construct temporary ford sites		X	X									
10-5	Prepare swim sites		X	X									
10-13	Construct M4T6 rafts		X	X									
10-22	Prepare crossing sites for NITEOPS		X	X									
10-23	Construct light tactical raft		X	X									
10-24	Construct light tactical bridge		X	X									
10-27	Construct flying ferry		X	X									
10-28	Construct trail ferry		X	X									
10-30	Construct and operate MAB rafts		X	X									
10-31	Construct a MAB bridge		X	X									
11-	CONDUCT INFANTRY OPERATIONS												
11-2/3	Conduct an area defense											X	
11-4	Conduct an area defense											X	
11-5	Conduct a deliberate attack											X	
11-6	Conduct an ambush patrol											X	
11-9	Conduct tank killer team operations											X	

Figure 6 (cont.)  
RELATIONSHIP OF ARTEP TASKS TO  
ROLES OF COMBAT ENGINEERS

ARTEP TASK NO.	ARTEP 5-145 TASKS	ROLES		ENHANCE FRIENDLY MOBILITY		IMPEDE ENEMY MOBILITY		PROVIDE PROTECTIVE SHELTERS		FIGHT AS INFANTRY		REDUCE ENEMY PROTECTION	
		MEASURES OF EFFECTIVENESS	MOVEMENT RATES/FRIENDLY MANUEVER UNITS	FRIENDLY ROUTE CAPACITY/TONS/VEHICLES/PEOPLE PER HOUR/DAY	MOVEMENT RATES/ENEMY MANUEVER UNITS	ENEMY ROUTE CAPACITY/TONS/VEHICLES/PEOPLE PER HOUR/DAY	Pk OF ENEMY WEAPONS VERSUS FRIENDLY TARGETS/LEVELS OF EXPOSURE	FIREPOWER POTENTIAL SCORE	Pk OF FRIENDLY WEAPONS VERSUS ENEMY TARGETS/LEVELS OF EXPOSURE				
13- 13-27 13-63 14- 14-7 17-	CONDUCT HORIZONTAL CONSTRUCTION OPERATIONS Improve and maintain roads Conduct snow removal operations CONDUCT VERTICAL CONSTRUCTION OPERATIONS Construct aircraft revetments CONDUCT FIELD WATER SUPPLY OPERATIONS	0	X X	X X									

Figure 6 (concl.)

RELATIONSHIP OF ARTEP TASKS TO  
ROLES OF COMBAT ENGINEERS

## DISCUSSION

The USAES Methodology described in the preceding section of the report provides a straightforward and useful approach to assessment of the impact of Combat Engineer Tasks on the effectiveness of maneuver units. It is emphasized that this methodology is, in its present form, intended as a roadmap to guide specific evaluations, not as a detailed model requiring only input data to produce results. Any application to specific problems will require not only input data but selection of appropriate combat models and development of scenarios which describe the combat environment, the maneuver elements and the engineer tasks to be evaluated. The remainder of this section of the report is devoted to brief discussions of a number of considerations that appear to be important in any specific application of this approach.

### Uniqueness of Engineer Tasks

In any evaluation of the contribution of Combat Engineer tasks to the overall effectiveness of a maneuver unit, it is essential that the unique, discrete nature of most of these tasks be kept in mind. To illustrate this point, consider a hypothetical unit consisting of ten rifle companies, one combat engineer company and appropriate non-combat support elements. In most combat models, the rifle companies are represented by firepower scores, which simply

### Importance of Scenarios

In Reference c., it is stated that "the criticality of most Engineer tasks to the outcome of a battle is in most cases scenario dependent." This is a very important point. Not only is it necessary that each scenario be tactically appropriate for the type of support activity under study, but also that the full range of possible scenarios, and their relative values be considered. The latter point is especially significant when results are stated in terms of trade-offs, such as "\$X expended for increased combat forces is as effective (in producing casualties) as \$Y expended for support forces."

Such trade-offs can be misleading unless they are based on a full spectrum of scenarios and on an evaluation of all of the capabilities of the support force.

### Statistical Significance

Because of the large number of parameters necessary to describe even a limited tactical situation, force structure and proficiency level, it is very unlikely that enough runs can be made to give any real statistical significance to the results. Accordingly, evaluations of this sort are best carried out on a case-by-case basis, with the relative importance and likelihood of occurrence of each case being considered separately (and perhaps subjectively).

add up the effect of all of the weapons, their roles of fire and individual kill probabilities. The effect of adding another rifle company to the unit (or of assigning the engineer company to "fight as infantry") is merely to increase the total firepower score by ten percent - not a decisive change in most situations. Most of the engineer tasks, however, can only be performed by the engineer company. Thus, the presence of the engineer company provides the difference between having and not having a bridge or a minefield. In many cases, such differences are decisive.

#### Selection of Models

As stated in the previous section, a combat model to be used in implementing this methodology must, in addition to meeting other criteria, be suitable for detailed evaluation of the supported force. Suitability, in this context, includes validity and reasonableness of results, sensitivity to changes in maneuver elements, and acceptability of resources requirements for operation. To phrase this point differently, all of the limitations of the model, viewed as a tool for evaluation of maneuver units, will apply even more strongly to its use as outlined here.

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### Historical Studies

Casual reading of Reference f. suggests that useful information on the value of combat support activities to a larger force could be obtained from brief historical studies carried out in the spirit of (3) above. That is, instead of attempting broad statistical analyses of historical data, limited case studies could be carried out to obtain insight into actual situations comparable, insofar as possible, to those used for model runs.

A number of statements from this book could be cited as possible examples of this type of study. Delays caused by the unexpected presence of a minefield, or by the threat posed by a dummy minefield are frequently mentioned in the description of armored combat in the African desert, for example. It would not appear that a large research effort would be required to obtain sufficient additional detail on situations like these to make them useful in the context indicated above.

### Measures of Effectiveness

There is a tendency for models that are primarily oriented toward casualties as a measure of effectiveness to yield results that seem high when compared with combat experience. Thus, in Reference e., there is a statement

that engagements are terminated when the casualty level reaches 50%. Numerous examples of significant engagements which were broken off at much lower casualty levels can be cited and this suggests that use of the higher level may underestimate the effectiveness of support activities. A similar tendency to overestimate rates of advance may also exist.

In this connection, it should be noted that the threat of certain types of obstacles, such as minefields, can have a significant effect, even when no real obstacle is present. Thus, evaluations which are based only on actual installations may seriously overestimate the resources required to achieve a specified result.

## CONCLUSIONS AND RECOMMENDATIONS

The principal conclusions and recommendations resulting from this effort are presented below. Because the project was accomplished in close coordination with USAES personnel, all of these items were discussed at length as the project progressed.

### Conclusions

(1) The USAES methodology described in this report represents a significant advancement in the evaluation of the contribution of engineer support to overall combat effectiveness. Used as a guide to the conduct of specific evaluations, at any level of resolution, it should be helpful both to analysts and to managers concerned with the context within which results of analyses are to be understood.

(2) The complexity and diversity of Engineer tasks, and the variety of published descriptions of these tasks, make it very worthwhile to construct and refine concrete descriptions, as presented in Figures 4 and 6, of the relationships among tasks and between tasks and the broad roles of the Combat Engineers.

(3) Although it is entirely appropriate to measure the effect of performance of Engineer tasks in terms of the overall effect of the supported force, care must be taken in the selection of models, scenarios and measures of effectiveness to insure that the uniqueness of these tasks is properly represented.

In particular, the use of casualty ratios without full consideration of other factors, such as time and space, can be misleading.

Recommendations

(1) The methodology described here should be used as a guide in carrying out detailed studies of Engineer effectiveness.

(2) The delineation of relationships among Engineer tasks and between tasks and roles, as presented in Figures 4 and 6, should be pursued further, both in general terms and in the context of specific evaluations.

(3) A modest effort, perhaps using advanced course students, should be devoted to locating historical examples of the effect of Engineer actions on battle outcome. Insofar as possible, examples closely related to current detailed evaluations should be sought.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) METHODOLOGY FOR RELATING ENGINEER PROCESSES TO BATTLEFIELD EFFECTIVENESS (MEREPROBE) ACN23989		5. TYPE OF REPORT & PERIOD COVERED FINAL
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) MR. MARTIN CHASE CHASE, ROSEN AND WALLACE, INC. ALEXANDRIA, VIRGINIA 22314		8. CONTRACT OR GRANT NUMBER(s) CONTRACT NO. DAAG29-76-0100 DELIVERY ORDER NO. 0134 <i>new</i> 24 June 1976
9. PERFORMING ORGANIZATION NAME AND ADDRESS CHASE, ROSEN AND WALLACE, INC. MR. MARTIN CHASE 901 N. WASH. ST., ALEXANDRIA, VA. 22314		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DD1498 dated 760701 DA 701127
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY RESEARCH OFFICE P.O. BOX 12211 RESEARCH TRIANGLE PARK, N.C. 27709		12. REPORT DATE 31 January 1977
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) U. S. ARMY ENGINEER SCHOOL ATTN: ATSE-CD-CS FORT BELVOIR, VIRGINIA 22060		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) SAME AS ITEM 16		
18. SUPPLEMENTARY NOTES Methodology to be evaluated is described in Coordination Draft Report, 1 Sep 75, "Impact of Engineer Proficiency on Combat Effectiveness of a Force", ACN 22957, US Army Engineer School, Fort Belvoir, Va. 22060.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) COMBAT ENGINEER TASKS MEASURES OF EFFECTIVENESS FORCE EFFECTIVENESS METHODOLOGY ARTEP TASKS		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) OBJECTIVE OF THE EFFORT IS TO OBTAIN AN INDEPENDENT EVALUATION OF A METHODOLOGY DEVELOPED IN-HOUSE BY THE ARMY ENGINEER SCHOOL. SPECIFIC TASKS WERE TO (1) REVIEW THE ENGINEER SCHOOL METHODOLOGY; (2) REVIEW RELATED DOCUMENTS AND RESEARCH PAPERS RELATED TO THE REQUIREMENT; (3) IDENTIFY STRENGTHS AND WEAKNESSES OF THE ENGINEER SCHOOL METHODOLOGY; AND (4) PROPOSE METHODOLOGY FOR ADDRESSING SIMILAR TYPE PROBLEMS BUT AT A LOWER LEVEL OF RESOLUTION, i.e., CORPS/THEATER.		

DD FORM 1473  
1 JAN 73

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