



US Army Corps
of Engineers

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THE ENGINEER MODEL
IMPROVEMENT PROGRAM
PLAN

ENGINEER
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THE ENGINEER MODEL
IMPROVEMENT PROGRAM
PLAN

Prepared by
Engineer Studies Center
US Army Corps of Engineers

August 1988

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To correct these and other problems, this plan provides a complete discussion of the quality of engineer modeling within the hierarchy of Army models, an identification of what engineer modeling improvements are needed (including terrain representation), and an assessment of which agency or activity is perhaps most appropriate and best equipped to make those improvements. This plan also provides a "best estimate" of how much analytic effort will be required, the dollar cost of that effort, and when the Army can expect the improvements to be achieved.

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EXECUTIVE SUMMARY

The Chief of Engineers has designated the Engineer Studies Center (ESC) as the Center of Engineer Modeling for the US Army Corps of Engineers (USACE) and the USACE point of contact for the Army Model Improvement Program (AMIP). As such, ESC has evaluated the current status of combat engineer modeling, identified a number of deficiencies in combat engineer modeling, and prepared this Engineer Model Improvement Program (EMIP) Plan which is designed to correct those deficiencies.

The initial focus of ESC's effort was on the fully automated models, including CASTFOREM, VIC, and FORCEM. ESC concentrated on these models first, believing that results of these efforts would have the most immediate payoff in force structuring and unit design initiatives. ESC also believed that improvements to the fully automated analytic models, when completed and approved, could be transferred fairly easily to the interactive and training models. More specifically, ESC addressed the following questions:

- * Does the structure of the models adequately represent the effects of engineer task execution?
- * Does the model represent engineer task execution on the battlefield, and can the requirements for, or capabilities of, an engineer force be measured?
- * Does the model use the quality and quantity of digitized terrain data needed to adequately measure the influence of terrain on the outcome of the battle?

ESC's study found that until 1979, the quality of engineer modeling was not good. This was because engineer-related studies were never high enough in priority relative to other studies in the Army's study program. Consequently, engineer representation in the Army's analytical models received little, if any, formal attention from the Army's analytic community. However, in 1979 an Army Model Improvement Program (AMIP) was initiated to improve and integrate the development, documentation, and implementation of a hierarchical family of computerized combat models. One rationale for the creation of AMIP was to ensure that the hierarchy of combat models properly represented functional areas. In particular, the models were to simulate combat, combat support, and combat service support in an adequate, valid, and consistent manner. This program, coupled with the US Army Engineer School's (USAES) own Engineer Modeling Program, helped to improve the situation. In fact, engineer modules were developed for each level of the AMIP hierarchy.

Despite these improvements, a number of problems still exist. Foremost among these are:

- * The Army land combat models do not adequately demonstrate the contribution that combat engineers make to the outcome of the battle.

- * The Army land combat models do not adequately measure the size of the engineer force needed to support the battle.
- * The availability of digital terrain data (DTD) is not adequate to support the Army's analytic community.

To correct these and other problems, ESC has developed this Engineer Model Improvement Program (EMIP) plan. This plan provides a complete discussion of the quality of engineer modeling within the hierarchy of Army models, an identification of what engineer modeling improvements are needed (including terrain representation), and an assessment of which agency or activity is perhaps most appropriate and best equipped to make those improvements. This plan also provides a "best estimate" of how much analytic effort will be required, the dollar cost of that effort, and when the Army can expect the improvements to be achieved. This EMIP Plan is therefore more than a plan; it is a strategy or direction for the engineer and the analytic communities to follow over the next few years. Major elements of this plan include:

- * Some changes to CASTFOREM to improve its combined arms representation.
- * Some major changes to VIC to expand the number of engineer tasks and effects that VIC represents.
- * A new FORCEM engineer module, in addition to changes in existing FORCEM elements.
- * The development of an engineer functional area model (EFAM).
- * The production of interim DTD.
- * An analysis of engineer task effectiveness.

From the beginning, ESC believed that the representation of engineer forces within the hierarchy of Army models could best and most consistently be achieved by a centralized program that represented the views of the senior engineer leadership. However, ESC also believed that a centralized program must be developed in coordination with the Army modeling community and be fully supported by the Army Models Committee. It is for these reasons that ESC has developed, staffed, and gained the engineer and Army analytic communities' approval of this EMIP plan. It has been designed to enrich the combat realism of the AMIP models. It is not intended to overburden any model with unnecessary detail. As such, ESC has carefully considered the impact of its recommendations on each specific model and feels that the recommended changes are appropriate and desirable to the Army community as a whole; not just the engineer community. Implementation of this plan, therefore, is in the best interest of the US Army.

LIST OF ABBREVIATIONS AND ACRONYMS

ACE	Assistant Chief of Engineers
ACSI.....	Assistant Chief of Staff for Intelligence
ADA.....	Air Defense Artillery
ADAM.....	Area Denial Artillery Munition
AFPDA.....	Army Force Planning Data and Assumptions
AFV.....	Armored Family of Vehicles
ALBE.....	AirLand Battlefield Environment
AMC.....	Army Models Committee
AMIP.....	Army Model Improvement Program
AMM.....	Army Mobility Model
AMMO.....	Army Model Improvement Program Management Office
AMS.....	Analytical Mapping System
AMSAA.....	Army Materiel Systems Analysis Agency
ANSI.....	American National Standards Institute
AO.....	area of operation
AOP.....	avenues of approach
AOS.....	aircraft operating surface
AR.....	Army Regulation
ARC/INFO.....	Arc and Information (a commercial GIS)
ARTBASS.....	Army Training Battle Simulation System
ARTY.....	artillery
ASAS.....	All Source Analysis System
ASL.....	Atmospheric Sciences Laboratory
AVLB.....	armored vehicle launched bridge
BP.....	battle position
BRDEC.....	Belvoir Research Development and Engineering Center
C2.....	Command and Control
CAA.....	Concepts Analysis Agency
CAMAA.....	Combined Arms Mission Area Analysis
CASTFOREM.....	Combined Arms and Support Task Force Evaluation Model
CBR.....	chemical, biological, and radiation
CCCA.....	Close Combat Capability Analysis
CCM.....	cross-country movement
CEM.....	Concepts Evaluation Model
CERL.....	Construction Engineering Research Laboratory
COE..	Chief of Engineers
COEA.....	Cost and Operational Effectiveness Analysis
COMMZ.....	communications zone
CONMOD.....	Conflict Model
CONUS.....	Continental United States
CORDIVEM.....	Corps/Division Evaluation Model
COSAGE.....	Combat Sample Generator
CRREL.....	Cold Regions Research and Engineering Laboratory
CRT.....	cathode ray tube

CS.....combat support
 CSS.....combat service support

 DA.....Department of the Army
 DB.....data base
 DCD.....Directorate of Combat Developments
 DDB.....digital data base
 DEH.....Directorate of Engineering and Housing
 DFAD.....Digital Feature Analysis Data
 DIGITAS.....Digital Terrain Analysis System
 DLMS.....Digital Landmass System
 DMA.....Defense Mapping Agency
 DMS.....Defense Mapping School
 DOD.....Department of Defense
 DS.....direct support
 DTD.....Digital Terrain (Topographic) Data
 DTED.....Digital Terrain Elevation Data
 DTSS.....Digital Topographic Support System

 EAC.....echelons above corps
 EAD.....echelons above division
 EFAM.....Engineer Functional Area Model
 EMIP.....Engineer Model Improvement Program
 EN.....engineer
 ESC.....United States Army Engineer Studies Center
 ETL.....Engineer Topographic Laboratories
 EW.....electronic warfare

 FAM.....functional area model
 FASCAM.....Family of Scatterable Mines
 FASTALS.....Force Analysis Simulation of Theater Administrative
 and Logistics Support
 FCZ.....forward combat zone
 FEBA.....forward edge of the battle area
 FIREFINDER.....Counter Battery Fire Finding System
 FM.....field manual
 FOA.....field operating agency
 FORCEM.....Force Evaluation Model
 FP.....firing point
 FAADS.....Forward Area Air Defense System
 FRG.....Federal Republic of Germany
 FY.....fiscal year

 G2.....intelligence officer
 G3.....operations officer
 GAO.....General Accounting Office
 GEMSS.....Ground Emplaced Mine Scattering System
 GIS.....geographic information system
 GNC.....Global Navigation Chart

GRASS.....Geographical Resources Analysis Support System
GSL.....Geographic Sciences Laboratory
HNS.....host-nation support

I/EW.....intelligence and electronic warfare
IMETS.....Integrated Meteorological System
IPR.....in-progress review
ITD.....Interim Terrain Data

JPL.....Jet Propulsion Laboratory

KM.....kilometer

LABCOM.....Harry Diamond Laboratories
LANDSAT.....Land Satellite
LAW.....light antitank weapon
LOC.....lines of communication
LOS.....line of sight
LOTS.....logistics-over-the-shore

MAA.....Mission Area Analysis
MAPS.....Map Analysis and Processing System
MC&G.....mapping, charting, and geodesy
MCP.....movement control point
MCS.....maneuver control system
MICOM.....US Army Missile Command
MOB.....Main Operating Base
MOEs.....measures of effectiveness
MOPMS.....Modular Pack Mine System
MOSS.....Multiple Overlay and Statistical System
MSGs.....models, systems, and games
MSR.....main supply route

NATO.....North Atlantic Treaty Organization
NBC.....nuclear, biological, chemical

ODB.....operational data base
OMNIBUS.....Operational Readiness Analysis
ONC.....Operational Navigational Chart
OPLAN.....operation plan

PAWS.....Portable Analysts' Work Station
PC.....personal computer
PM.....project manager
POC.....point of contact

POL.....petroleum, oil and lubricants
 POMCUS.....prepositioning of materiel configured to unit sets
 PPDB.....Point Positioning Data Base
 PTADB.....Planning Terrain Analysis Data Base

QRMP.....Quick Response Multicolor Printer

R&D.....research and development
 RAAMS.....Remote Anti-Armor Mine System
 RCZ.....Rear Combat Zone
 RDTE.....research development test evaluation
 REMBASS.....Remote Battlefield Sensor System
 ROK.....Republic of Korea

SP.....Start Point
 STD.....special terrain data
 SWO.....staff weather officer

TA.....tactical areas
 TAC.....Terrain Analysis Center
 TACOM.....Tank and Automotive Command
 TACWAR.....Tactical War
 TAPS.....Terrain Analysis and Planning System
 TAWS.....Terrain Analysis Work Station
 TB.....terrain and barriers
 TD.....terrain data
 TDA.....tactical decision aid
 TOPO.....topographic
 TPC.....Tactical Pilotage Chart
 TRAC.....TRADOC Analysis Command
 TRAC-FLVN.....TRADOC Analysis Command, Fort Leavenworth
 TRAC-WSMR.....TRADOC Analysis Command, White Sands Missile Range
 TTADB.....Tactical Terrain Analysis Data Base
 TRADOC.....Training and Doctrine Command
 TTD.....tactical terrain data

US.....United States
 USA.....United States Army
 USACE.....United States Army Corps of Engineers
 USAES.....United States Army Engineer School
 USAF.....United States Air Force
 USAICS.....United States Army Intelligence Center and School
 USMA.....United States Military Academy
 UTM.....universal transverse mercator

VIC.....Vector-in-Commander
 VIP.....Vector-in-Commander Pre-processor

VMUG.....VIC Model Users Group
VOD.....vertical obstruction data

WES.....Waterways Experiment Station
WSMR.....White Sands Missile Range

THE ENGINEER MODEL IMPROVEMENT PROGRAM PLAN

I. INTRODUCTION

1. Purpose. The Engineer Model Improvement Program (EMIP) is a comprehensive effort that is designed to ensure that engineers are properly represented in the Army's land combat models. This paper outlines a plan that was developed by the US Army Engineer Studies Center (ESC) to initiate and manage that program. This plan was developed in support of the US Army Engineer School (USAES) and in conjunction not only with the USAES, but also the broader "engineer community" and the affected Army "analytic community."

2. Scope. This plan:

- a. Identifies the problems associated with engineer representation in current Army models.
- b. Identifies and prioritizes the work required to correct these problems.
- c. Schedules this work over a 4-year period, with emphasis on completing the critical tasks within 2 years.
- d. Estimates the analytic effort required, and displays annual funding and manpower requirements.
- e. Addresses the question of who is available to do the work.

3. Background.

a. **The Army Model Improvement Program (AMIP)**. In 1979, the *Review of Army Analysis* found several deficiencies in the Army's computerized combat models: poor documentation, poor response to study needs, inconsistent results, differing data assumptions, lack of interface structure, and limited (or no) functional area representation.¹ As a result, a directive was implemented for an Army Model Improvement Program (AMIP) in April 1980. Tasks and responsibilities within the AMIP are described in Army Regulation (AR) 5-11.²

(1) The goals of the AMIP were to improve the Army's analytical capability, improve model consistency and responsiveness, establish data base design and management, apply emerging computer technology, develop training applications, and stem model proliferation. These goals were to be

¹*Review of Army Analysis*, Department of the Army (DA) Special Study Group, April 1979.

²*Army Model Improvement Program*, AR 5-11 (DA, 15 August 1983).

accomplished by developing, documenting, and implementing a hierarchical family of computerized combat models which are supported by functional area models (as shown in Figure 1).

(2) Headquarters, Department of the Army delegated primary responsibility for overseeing AMIP activities to the Commanding General, US Army Training and Doctrine Command (CG, TRADOC). An AMIP Management Office (AMMO) was established to assist in coordinating and directing AMIP activities. AMIP advice and guidance were to be provided by the Army Models Committee (AMC), which was formed in 1981 as a continuing committee. The chairperson of the AMC is the Deputy Under Secretary of the Army for Operations Research.

(3) The USAES was designated by the CG, TRADOC, to be the engineer proponent for AMIP modeling efforts. As such, the school has had the overall responsibility of ensuring that the engineer functional area is properly represented in the AMIP models.

b. US Army Corps of Engineers' (USACE) involvement in AMIP. USACE has been involved primarily in a support role. As such, it has provided model development resources to USAES and, in turn, the Army modeling community. Both the Construction Engineering Research Laboratory (CERL) and the Waterways Experiment Station (WES) have had engineer modeling programs, some of which pre-date the 1980 establishment of AMIP. Thus, combat engineer modeling has been a high priority effort in USACE, especially in their research and development programs.

c. ESC involvement in AMIP. ESC's involvement with AMIP began in the fall of 1985. During October and November of that year, a series of messages was sent by USAES, USACE, and the TRADOC Analysis Command (TRAC), all in reference to a possible increase in the engineer staff at HQ TRAC. The primary objective was to help TRAC model the value of engineers as members of the combined arms team. As a result, USACE proposed to assign an engineer officer to ESC, with duty station at HQ TRAC. The mission, functions, and operating procedures associated with this new position were formally agreed to in a 12 June 1986 Memorandum of Understanding between the Commandant, USAES and the deputy commanding generals of both TRAC and USACE (see Annex G). In August 1986, a former engineer battalion commander was selected to fill this newly created position.

AMIP MODELS

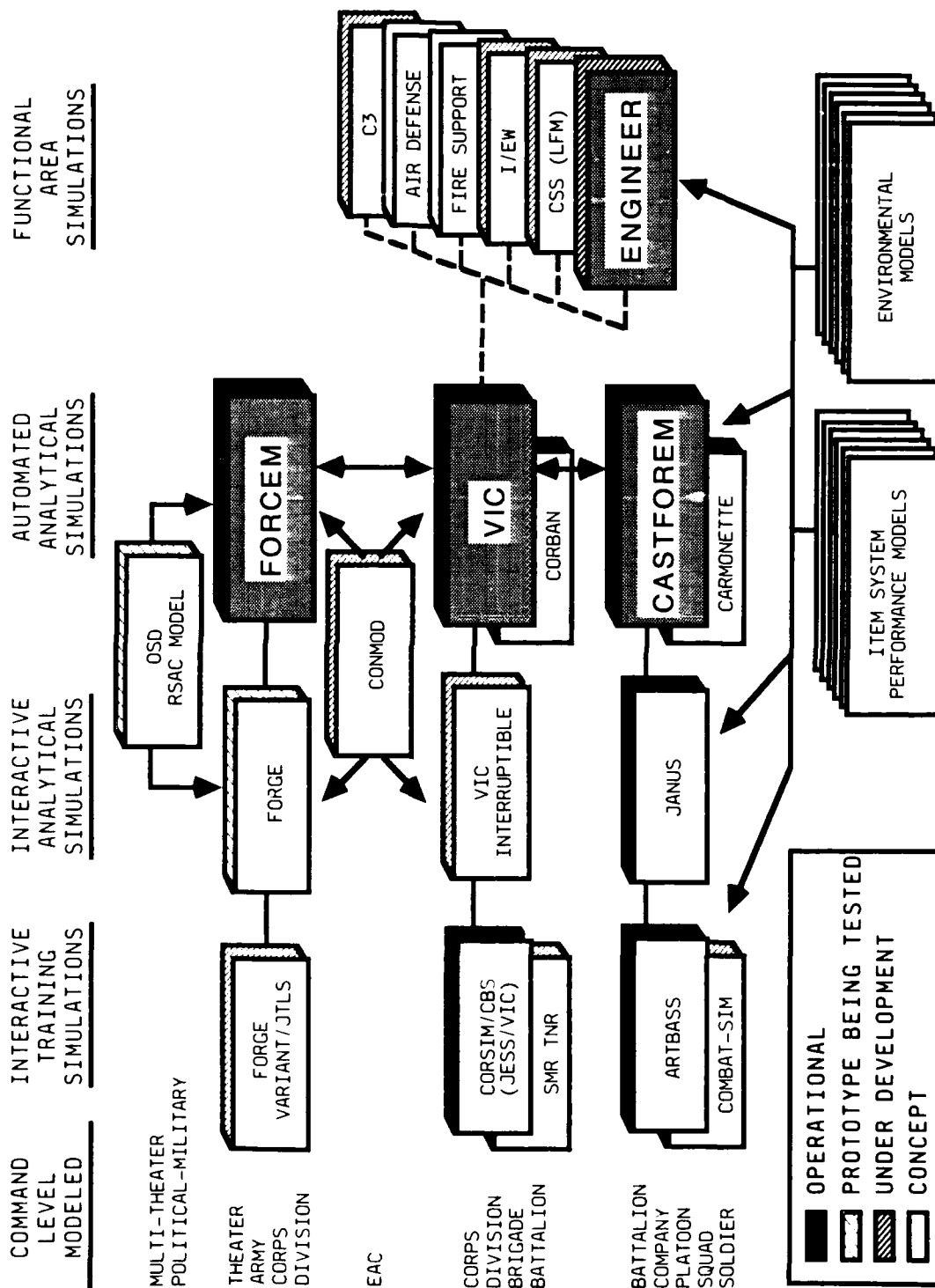


Figure 1

(1) USACE went beyond simply stationing one ESC officer at Fort Leavenworth. The CG, USACE, also assigned ESC a combat engineer modeling mission. ESC's experience with worldwide engineer assessments, evaluation of engineer unit designs, and evaluations of engineer doctrine placed it in a unique position to be a focal point for USACE modeling support. To this end, on 3 December of 1986 the CG, USACE, also assigned to ESC the following missions:

(a) Monitor and evaluate the representation of engineers within the hierarchy of Army models and provide, in coordination with USAES, recommendations to the AMC.

(b) Provide primary USACE interface with the AMMO and other AMIP organizations on matters relating to engineer modeling.

(c) Serve as the USACE point of contact for the Army Staff on all matters pertaining to AMIP engineer modeling.

(d) Serve as USACE program manager for AMIP engineer model improvements provided by USACE laboratories.

(2) To clearly delineate ESC's relationship with the USAES, the CG, USACE, specifically highlighted the following:

The designation of ESC as the Center of Combat Engineer Modeling within USACE is intended to strengthen the engineer community's involvement in modeling. This designation does not circumvent the duties and responsibilities of the USAES as the Engineer Proponent with its prescribed responsibilities under TRADOC for modeling. ESC's AMIP work and modeling initiatives will be fully coordinated with, and concurred in, by the USAES.³

d. ESC's involvement in the Engineer Model Improvement Program (EMIP). From the beginning, ESC believed that the representation of engineer forces within the hierarchy of Army models could best and most consistently be achieved by a centralized program that represented the views of the senior engineer leadership. However, ESC also believed that a centralized program must be developed in coordination with the Army modeling community and be fully supported by the AMC. It is for these reasons that ESC has developed,

³Letter, US Army Corps of Engineers, dated December 3, 1986, subject: Engineer Studies Center's Role in Engineer Modeling.

staffed, and gained the engineer and Army analytic communities' approval of this EMIP plan.

4. Limits. ESC's combat engineer modeling mission is limited to those land combat models included within the hierarchy of Army models. Furthermore, this EMIP plan focuses only on improvements that are needed to the fully automated models, which include the Combined Arms and Support Task Force Evaluation Model (CASTFOREM), the Vector-in-Commander (VIC) model, and the Force Evaluation Model (FORCEM). However, this plan also addresses the development of an Engineer Functional Area Model (EFAM).

5. Method. ESC used the three-step approach shown in Figure 2 to develop this plan:

a. Step one. ESC assessed the current level of engineer representation in the fully automated AMIP models. During its analyses, ESC focused attention on three related aspects of engineer modeling by asking the following questions of each model:

(1) Engineer task effectiveness. Does the structure of the model adequately represent the effects of engineer task execution?

(2) Engineer unit effectiveness. Does the model represent engineer task execution on the battlefield, and can the requirements for, or capabilities of, an engineer force be measured?

(3) Terrain representation. Does the model use the quality and quantity of digitized terrain data needed to adequately measure the influence of terrain on the outcome of the battle?

b. Step two. ESC established the desired level of engineer representation in the AMIP models. The primary criteria used to develop this assessment included: an ESC analysis of engineer tasks, input from the Army modeling community, and USAES guidance.

c. Step three. Based on the discrepancies between the current and desired levels of engineer representation, ESC developed an aggressive model improvement plan that addresses: the necessary enhancements to CASTFOREM, VIC, and FORCEM; requirements for an EFAM development; and digitized terrain data base requirements to support all models.

EMIP METHODOLOGY

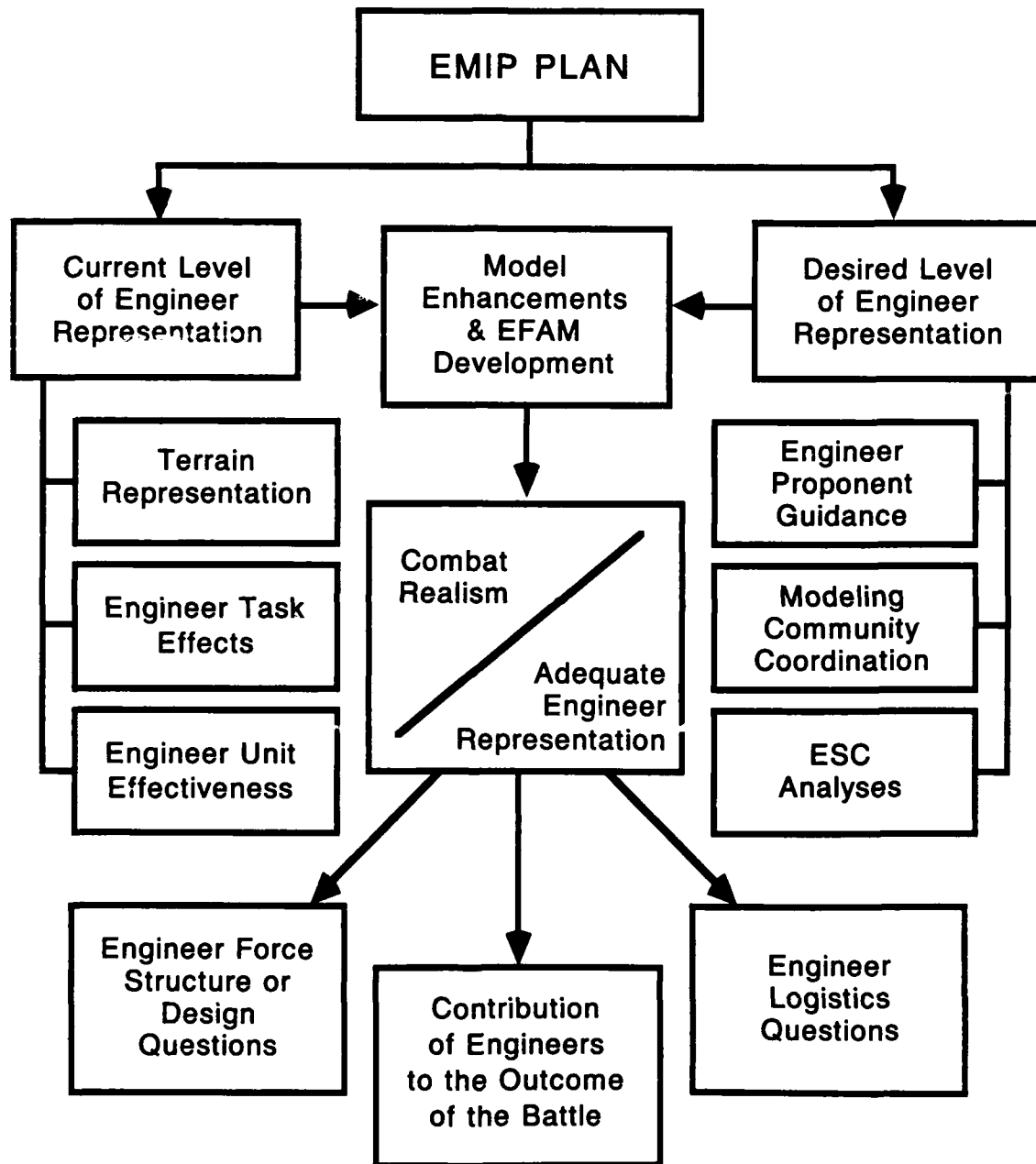


Figure 2

II. ENGINEER FUNCTIONS AND ARMY MODELING

6. Introduction. As previously stated, the purpose of the EMIP is to ensure that engineers are properly represented in the Army's combat models. ESC has translated this purpose in a two-fold objective. First, the models should realistically represent the combined arms conflict. This objective cannot be accomplished without a realistic representation of the role that combat engineers play in the combined arms team. Second, the degree to which the engineer functions are represented in any particular combined arms model should be commensurate with the model's intended use and level of resolution. With this in mind, ESC established guidelines for the types of engineer tasks that should be considered in high-, mid-, and low-resolution models, and used these guidelines to evaluate CASTFOREM, VIC, and FORCEM. In this section ESC summarizes that effort, generally describes the engineer's role in a combined arms environment, and explains how this role should be modeled.

7. Engineer Missions. Army Field Manual (FM) 100-5, *Operations*, gives the Army's basic warfare doctrine and describes how combat engineers contribute to the combined arms team. Engineer missions are developed in more detail in: FM 5-100, *Engineer Combat Operations*; FM 5-101, *Mobility*; FM 5-102, *Counter mobility*; FM 5-103, *Survivability*; and FM 5-104, *General Engineering*. These FMs define the following combat engineer mission areas:

a. **Mobility**. US forces conduct mobility tasks to obtain and maintain the freedom of both tactical maneuver and operational movement. Mobility missions include: breaching obstacles, conducting river crossing operations, and preparing and maintaining pioneer trails.

b. **Counter mobility**. Counter mobility efforts have an ultimate goal of delaying, stopping, or channelizing the enemy. Engineers perform counter mobility tasks by installing linear obstacles (e.g., minefields, antitank ditches) or point obstacles (e.g., road craters, bridge demolitions).

c. **Survivability**. The concept of survivability includes all aspects of protecting personnel, weapons, and supplies while simultaneously deceiving the enemy. Survivability tactics include: constructing fighting and protective positions for both individuals and equipment; and using concealment, deception, and camouflage.

d. **Sustainment engineering.** Sustainment engineering primarily supports the rear areas which, in turn, support the forward-deployed force. It includes functions such as maintaining main supply routes, repairing airfield damage, and maintaining rear area facilities.

e. **Topographic engineering.** Topographic engineering assists field commanders in using the terrain more effectively. Topographic functional areas include terrain analysis, map production (cartography, map reproduction, and topographic survey), and map distribution.

8. **Engineer Employment.** Engineer troop units provide support throughout the theater of operations. Combat engineer units are assigned missions in the forward combat zone (FCZ) in the division and corps areas. Engineer combat heavy battalions are assigned missions in both the FCZ and the communications zone (COMMZ). Separate engineer companies and teams are assigned where needed.

a. **Support in the division area.** Each US Army division has an organic divisional engineer battalion which operates as part of its combined arms team. Each engineer battalion's companies are normally associated with a particular divisional brigade or task force. These engineer companies are normally placed in direct support or under operational control (OPCON) of the supported force. Engineer battalions which are organic to airborne, air assault, and light infantry divisions have fewer resources than the engineer battalions in the other divisions. They have fewer personnel, less earth moving equipment, and no bridging capability. Separate brigades and armored cavalry regiments also have organic engineer companies. An engineer terrain team of the theater topographic engineer battalion normally supports each division.

b. **Support in the corps area.** The composition of engineer units in a corps area depends primarily on the mission, threat, and terrain in the specific area of operations. It also depends on the availability of host nation assets and the size of the supported maneuver force. In general, for a five-division corps in the European theater, the doctrinal engineer force might include: a brigade headquarters; two or more group headquarters; 12 corps battalions; three heavy battalions; six float bridge companies; four medium girder bridge companies; six combat support equipment companies; two dumptruck companies; a cartographic company; five divisional terrain teams; a

corps terrain team; a topographic survey platoon; and cellular teams for real property maintenance activities, as required.

c. **Support in the COMMZ.** The requirements for engineer support in the COMMZ depend largely on the character, magnitude, and phasing of base development operations. Base development includes the initial beddown of logistics units; the repair and renovation of Lines of Communication (LOCs) and facilities needed to support the receipt, storage and distribution of war materiel; and the logistics base expansion required to establish a mature theater. Because the size and make-up of the engineer COMMZ is so theater and operation plan (OPLAN) dependent, it is unproductive to provide a sample force sizing for the COMMZ. However, for a major theater, the engineer force would doctrinally contain an engineer command headquarters and several brigade headquarters (each with two or more group headquarters). Depending on the mission assigned, the group headquarters would command and control a blend of combat heavy battalions and construction support, dump truck, pipeline, port construction, and bridge companies. The engineer command and brigades would also control the numerous topographic units, as well as the facility-oriented companies and teams assigned to the theater.

d. **Support to other services and agencies.** Army engineers may also be directed to support other services and agencies in the theater of operations. Currently, Army engineers support the US Air Force (USAF) by accomplishing follow-on airfield war damage repair and restoration to damaged pavements and facilities, as well as all new construction requirements. Army engineers also assist with emergency war damage repair and beddown requirements that exceed Air Force civil engineering capabilities. The responsibility to support the Air Force is a major mission which places severe demands on several Army engineer units (combat battalion heavy, construction support equipment companies, and utility detachments) in a theater of operations.

9. **Engineer Tasks.** The above discussion indicates the diversity of tasks that engineers are expected to perform on the battlefield. Figure 3 groups these tasks into 16 broad task categories based on the interaction between engineer functions and other combat functions (see Annex F). ESC used these broad task categories as a foundation from which to develop more

ENGINEER TASK CATEGORIES

1. Install linear obstacles (minefields, tank ditches...)
 2. Install point obstacles (road craters, bridge demolition...)
 3. Prepare fighting positions for direct fire systems (tanks, TOWS...)
 4. Prepare positions for indirect fire & other systems (artillery, ADA, CP,...)
 5. Breach obstacles in the assault (breach minefields, span short gaps...)
 6. Improve assault breaches for follow-on forces (clear minefields, widen lanes...)
 7. Conduct river crossing operation in the assault (bank clearing, rafting, assault bridging...)
 8. Improve river crossing site for follow-on forces (fixed bridging, float bridging...)
 9. Maintain main supply routes (fill craters, build up worn shoulders...)
 10. Pioneer trail preparation & maintenance (route clearing, soil stabilization...)
 11. Forward airlanding facility preparation & maintenance (air strip clearing, soil stabilization...)
 12. Site preparation & maintenance for combat support & combat service support units (access road, site clearing...)
 13. Rear area facility rehabilitation & maintenance (building conversion, damage repair...)
 14. Airfield damage repair (crater repair, rubble clearing...)
 15. Port & waterfront facilities construction & repair (pier repair, storage facility rehabilitation...)
 16. Other (engineer raids, nuclear rubble removal...)
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Figure 3

specific recommendations about the modifications which are needed to better represent engineer play in specific models. ESC observed that:

a. There are certain engineer task categories in Figure 3 that are outside the scope of high-resolution models (i.e. CASTFOREM). For example, the short engagement times and the small battlefield size that are represented in high-resolution models make it impractical to represent such tasks as rear area facility damage repair and improving river crossing sites for follow-on forces.

b. Most engineer task categories can be represented in mid-resolution models (i.e., VIC). Since current mid-resolution models include the corps service areas, they come closest to covering all of the engineer task categories identified in Figure 3. Mid-resolution models also have the architectural structure to accommodate the inclusion of most engineer tasks in substantial detail.

c. Some engineer tasks cannot be explicitly represented by low-resolution models (i.e., FORCEM). The design of current low-resolution models is such that even the general list of 16 task categories cannot be explicitly represented at this level of aggregation. On the other hand, low-resolution models can address rear area operations that cannot be represented in models of other levels of resolution.

10. Engineer Modeling and CASTFOREM. CASTFOREM is a high-resolution, two-sided, stochastic simulation of a small combined arms conflict lasting, at most, 1-1/2 to 2 hours. It enjoys general acceptance throughout the modeling community. The model simulates a fire-fight between a defender of battalion-size (or smaller) unit against an attacker of regimental-size (or smaller). A typical CASTFOREM battle area is represented by 20 x 20 kilometers of terrain, graduated into 100 meter grid cells.

a. Background. In 1981, TRADOC Analysis Command, White Sands Missile Range (TRAC-WSMR) (then the TRADOC Systems and Analysis Activity), developed CASTFOREM as the battalion-level AMIP model. As originally conceived, this model is battalion task force level in scope and plays individual vehicles and weapon systems. Its capacity to handle complex scenario situations and detailed input data has made it an excellent replacement for CARMONETTE, the predecessor high-resolution model.

b. **Engineer modeling considerations.** CASTFOREM was designed to represent the detailed operations of the combined arms and support task force. Its primary purpose is to determine the effectiveness of units and individual systems. As such, only the "vital" engineer tasks should be considered for representation in CASTFOREM.⁴ These vital tasks include: preparing fighting positions (direct-fire positions); installing linear obstacles; breaching obstacles in the assault; installing point obstacles; preparing fighting positions (indirect-fire and other systems); and conducting river crossing operations in the assault. Unfortunately, CASTFOREM has limited ability to explicitly play the execution of these tasks. This is due to the short duration of simulated battle (only 2 hours), the small size of the terrain box (only 400 square kilometers), and the high resolution of the maneuver units (usually company size). Nevertheless, the effects of these tasks are critical to CASTFOREM realism.

11. Engineer Modeling and VIC. VIC is a two-sided, deterministic computer simulation of combat in a combined arms environment. The model is designed to provide a balanced representation of the major force elements of a US Army corps in a tactical campaign. The modular program structure represents friendly air and land forces and a commensurate enemy force in a mid-intensity battle. The model is event-stepped for maneuver elements and time-stepped for calculating support effects. Maneuver units in VIC initially move along scripted paths. Decision tables exercise command and control in the automated simulation. The model has a pre-processor for constructing input data files and comprehensive post-processors for displaying model results. VIC users generally represent terrain in 4 x 4 kilometer grid squares. Three terrain data classes (vegetation, relief, and linear obstacles and features) normally affect the modeled maneuver units' movement and visibility. VIC has been used by TRAC-WSMR and TRADOC Analysis Command, Fort Leavenworth (TRAC-FLVN) on six major studies and typically simulates three to six days of combat.

a. **Background.** In 1982, TRADOC established a requirement for a corps-level model in which AirLand Battle Doctrine could be represented and

⁴See Annex F for definitions of "vital," "critical," "essential," and "necessary" engineer tasks.

studied. TRAC-WSMR decided to take advantage of, and improve upon, the best features of existing models rather than to develop a completely new model. Specifically, VIC was based on: the Vector-2 model's representation of ground combat (developed by Vector Research, Incorporated), and the USAF's Commander Model's representation of the air war (which evolved from the Talon Model). In 1985, a review committee, which was appointed by the AMC, recommended VIC as the Army's corps/division-level model. In 1986, VIC was adopted into the Army's hierarchy of simulation models under AMIP, replacing the Corps/Division Evaluation Model (CORDIVEM) simulation. VIC was placed under configuration management by HQ TRAC in April 1987.

b. **Engineer modeling considerations.** According to AR 5-11, VIC is to be used for force design and development of concepts, doctrine, and tactics for corps, divisions, and brigades. It will also be used to determine resource requirements for sustained operations and to study materiel systems that are organic to, or have an influence on, the capabilities of corps, divisions, or brigades. Because it is the Army's mid-resolution corps/division simulation model, VIC should, as a minimum, represent the engineer tasks that are performed forward of the corps rear boundary. But, unlike CASTFOREM, which focuses on the effectiveness of individual weapon systems, VIC represents the interactions of the various combat, combat support (CS), and combat service support (CSS) functional areas. Therefore, the execution of engineer tasks should be modeled, as well as the effects of those engineer tasks.

12. Engineer Modeling and the Force Evaluation Model (FORCEM). FORCEM is a two-sided, time-stepped, deterministic theater-level wargame. It plays both ground and air combat. Unlike most other theater models, FORCEM has a multi-tiered decision making framework and includes the role of CSS forces at echelons above corps. FORCEM has three major functional areas: situation development, command and control, and an activity portion consisting of combat and support elements. Situation development builds a perception base by simulating the gathering and processing of intelligence information, and the transmission of that information among headquarters. The situation data is used by command and control for decision making at corps, army, and theater headquarters. The decision making process controls unit and resource dispositions using hard-wired decision rules controlled by various input

parameters. Combat occurs at several levels: at the maneuver unit level; at the air war level; and at the deep strike artillery and surface-to-surface missile level. Medical, supply, transportation, maintenance, vehicle recovery, personnel, and engineer functions comprise support activities currently modeled in FORCEM.

a. **Background.** In July of 1981, AR 5-11 tasked the US Army Concepts Analysis Agency (CAA) with the responsibility for the theater level component of the AMIP hierarchy -- the Force Evaluation Model. FORCEM development began at CAA in 1982, and the first working version was completed in 1985. It was used in a demonstration mode on the US Army Operational Readiness Analysis-1985 (OMNIBUS-85) Study. Subsequently, it was used for theater analyses in both OMNIBUS-86 and the Combat-Support Ratio Study. With constrained manpower resources CAA has found, however, that study support has been at the expense of making desired model refinements and improvements. A recent decision has been made to push model development and forego study support for the remainder of 1988.

b. **Engineer modeling considerations.** CAA designed FORCEM to become the Army's principal theater-level wargame. While it has been used successfully on several studies, FORCEM has not reached its full potential as outlined in AR 5-11. Originally, FORCEM was to support both capability and requirements analyses, relying on the division/corps results from CORDIVEM. To date, FORCEM has evolved into a capabilities model that relies on division-level combat samples from Combat Sample Generator (COSAGE), and on Force Analysis of Theater Administrative and Logistics Support (FASTALS) to round out those portions of the force which are not represented in FORCEM (e.g., engineers). CAA is constantly improving FORCEM so that it will eventually attain its desired functional capacity. Once these improvements are made, FORCEM could then be used to support both program analyses and force design. The "ideal" engineer representation in FORCEM would simulate all the tasks in Figure 3. Such an "ideal" version is, of course, realistically unattainable because of the way engineer functions are represented. Also, the level of resolution of engineer functions must be compatible with the other functional components in the model. The challenge then is to adapt engineer representational needs with FORCEM's design, components, and computational limits.

III. CONCLUSIONS

13. The Quality of Engineer Modeling Has Not Been Good. Historically, there have been serious deficiencies in the modeling of engineer functions in available force-on-force simulations. From the early 60's to the late 70's, engineer representation in the Army's land combat simulations was minimal, at best. The lack of adequate engineer representation in the Army's analytical models received little, if any, formal attention from the Army's analytic community. This general state of neglect was probably rooted in the ad hoc process that was commonly used at the time to develop models. Engineer-related studies were never high enough in the queue to receive anything but casual interest from the modeling community. Since these combat models were being used in almost all Army studies of combined arms' systems, engineers were at a severe disadvantage. Because of inadequate engineer representation in these models, the engineer community could not demonstrate to the Army the engineers' contribution to combat force effectiveness. Conversely, the engineers were also not able to analyze engineer material and equipment requirements within the context of a combined arms simulation. This inadequacy of combat engineer modeling was recognized by sources outside the engineer community in a 27 February 1980 memorandum in which the Army Chief of Staff urged the Chief of Engineers "...to relook the manner in which engineers state and support combat engineer systems."

14. The Situation Has Improved. Beginning in 1979, the Army moved toward the development of a hierarchy of combat and support models under AMIP. This was a positive step away from the ad hoc model developments that had previously thwarted engineer representation. About the same time, the USAES established an Engineer Modeling Program. The primary goal of the Engineer Modeling Program was to develop an engineer module for AMIP's corps level model (initially called the Corps Battle Game and later called CORDIVEM). Under the auspices of AMIP and the Engineer Modeling Program, engineer modules were developed for CASTFOREM, CORDIVEM, and FORCEM.

15. Problems Still Exist. Despite recent improvements in the representation of engineers in the AMIP models, problems do still exist. They include:

a. The Army land combat models do not adequately demonstrate the contribution of combat engineers to the combined arms battle. ESC believes that problems still exist with the current engineer representation in the following AMIP models:

(1) CASTFOREM. The Engineer Module is in a state of transition. Although CASTFOREM currently simulates engineer activities very modestly, coding and decision tables have recently been added which will model mobility and countermobility tasks explicitly. Unfortunately, TRAC-WSMR has not yet published the results of the CASTFOREM runs which will validate the coding and decision tables. Once the changes to the Engineer Module have been accepted, CASTFOREM will still lack the ability to simulate dynamic delivery of mines, special stand-off mining systems (i.e., WAM) and obstacle combinations (complex obstacles).

(2) VIC. In VIC, only engineer units at the lowest level can perform work: minefield teams (emplace only); linear obstacle teams (emplace only); bridging teams; and survivability teams (defensive position construction). While VIC does account for unit-allocated equipment and has the capability to attrite specific classes of equipment, the availability and capability of that equipment does not affect the rate at which engineer units accomplish their tasks.

(3) FORCEM. To find engineer play, one must look to models that support FORCEM: COSAGE produces the samples used for combat results calculations; and FASTALS determines engineer unit resource requirements for COMMZ tasks through the force round-out process. After looking at engineer play or treatment across all three models, ESC found the following:

(a) COSAGE considers only one engineer-related activity -- the breaching of pre-emplaced minefields. The method used to extrapolate results from combat samples, as well as the samples themselves, appears to ignore the role of engineer forces. Thus the important role of divisional and corps engineers on the battlefield is ignored.

(b) Although FASTALS does consider some engineer tasks, it does not include several "vital" tasks that have important resource and force effectiveness implications. Task estimates appear to use workload parameters that are both overly general and subjective. More importantly, since it is a

requirements model, FASTALS cannot indicate what effect engineers have on the conduct of the war.

(c) FORCEM also fails to consider such tasks as US Army engineer assistance to USAF engineers when airbase damage or beddown requirements exceed USAF capability. Even if VIC replaces COSAGE as the combat sample generator, the engineer work which occurs in the corps rear (the gap between COMMZ and FCZ) will have to be addressed.

b. Engineer-sponsored studies are typically not high on the TRADOC list of priority studies. Even though historically the combat engineer has been an indispensable member of the combined arms team, studies to support the modernization of the engineer force cannot successfully compete for scarce TRAC modeling resources. The consequences of this low priority for engineer studies is twofold. First, since most of the enhancements to production models (i.e. CASTFOREM, VIC, and FORCEM) are study-driven, engineer representation in these models does not evolve as rapidly as does the representation of other higher priority functional areas. (The top priority at TRAC is study support -- not model research and development.) Second, the USAES must look elsewhere for modeling support. The USAES has access to several non-AMIP models, but none that are both adequate to address engineer-specific questions and provide credible results in the eyes of the Army's analytical community. The engineer study program suffers on both counts.

c. The availability of digital terrain data (DTD) is not adequate to support the Army's analytic community. Identification and production of DTD to support the Army's analytic community has been inadequate. Most DTD coverage for the Army's OPLANs is for locations supporting TRADOC-approved scenarios in the Federal Republic of Germany (FRG). As a result, CAA cannot conduct simulations which adequately represent terrain (and therefore engineer functions) in their other theater-level studies. DTD inadequacies also preclude agencies such as ESC and Army Materiel Systems Analysis Agency (AMSAA) from adequately representing terrain in their VIC or CASTFOREM simulations of combat in world areas other than the FRG.

IV. RECOMMENDATIONS

16. Only a Few Changes Are Needed in CASTFOREM. For engineer unit and force structure studies, CASTFOREM's applicability is limited. It cannot be expected to realistically model the engineer's flexible and responsive support structure. It is, however, an invaluable tool for evaluating the effects of specific engineer tasks (e.g., emplacing obstacles) or the operational effectiveness of individual engineer systems. With the recent improvement of the Engineer Module, USAES and TRAC-WSMR have made substantial progress toward adequately representing engineers in CASTFOREM. The first priority will be for USAES and TRAC-WSMR to publish the results of the validation of the mobility and countermobility coding and decision tables. A few additional changes are recommended at this time to improve the realism of CASTFOREM's combined arms representation. Those improvements are discussed in detail in Annex A.

17. VIC Requires an Expansion in the Number of Engineer Tasks and Effects That Are Currently Represented. VIC was designed to represent the interactions of the various combat, CS, and CSS functional areas. As an analytical tool, its purpose is to support design and structure tradeoff analyses of Army organizations such as brigade, division and corps. (VIC can also support studies of certain item systems organic to major organizations.) It is for these reasons that VIC must provide a reasonable and balanced representation of each functional area, and accurately portray the contribution of each functional area to the combined arms conflict. Currently, VIC represents a few engineer tasks and effects well. However, many tasks and effects are represented poorly or not at all. To maintain a reasonable and balanced representation in VIC, engineer units should continue to be modeled explicitly. However, the representation of engineer unit capability under a more flexible modeling arrangement could improve the realism of the current tasks played in the model and permit the inclusion of additional engineer tasks. Annex B of this report identifies 37 improvements that ESC recommends be made to the engineer representation in VIC.

18. Adequate Engineer Representation in FORCEM Will Require a New Engineer Module, in Addition to Changes in Existing FORCEM Elements. FORCEM was designed to become the Army's principal theater-level wargame. Looking to

that time, FORCEM will have to be improved if it is to fairly represent engineer activities in the theater well enough to evaluate capabilities and calculate requirements. Moreover, the improvements are interrelated; accomplishing one without making progress in others will gain nothing. Unless terrain and installations are satisfactorily represented, the effects they have on various modeled units and processes cannot be calculated. Nor can engineer tasks have any reasonable basis without adequately representing the object on which they work. Annex C of this report identifies the specific improvements ESC recommends for FORCEM.

19. The Engineer Community Needs a Functional Area Model. Each proposal for improving the Army's equipment, organization, or training must be analyzed in detail to demonstrate the cost and operational effectiveness of the proposed change. Those organizations or systems with the greatest perceived pay-off are normally chosen for acquisition. Combat engineer systems, lacking the support of robust analytical techniques, often do not make the initial cut. There are several reasons for this. First, the Army land combat models do not adequately demonstrate the contribution of engineer systems to the combined arms battle, much less have the breadth and depth to address specific engineer issues. Second, even if they did, engineer-sponsored studies are typically not high on the TRADOC list of priority studies. Therefore, they are often performed without modeling support from TRAC, using models that do not have the credibility that AMIP models enjoy. A developmental program should be undertaken with the ultimate goal of providing USAES with an appropriate, analytically acceptable, and Army approved corps/division-level model. Annex D to this report presents the requirements specifications for an EFAM. Generally, the model should be stand-alone, but logically linked to VIC. It must be capable of addressing the following types of analyses:

- a. Engineer force structure or design questions.
- b. Engineer logistics questions.
- c. Contribution of engineers to the combined arms conflict.

20. The Army Needs More Extensive Area Coverage For DTD. ETL included the needs of the Army analysis community in their 1984 study, *Army Digital Topographic Data Requirements*. These requirements were validated by ODCSINT and were formally presented to the Defense Mapping Agency (DMA) in October

1984. However, as discussed in Annex E, DMA does not plan to begin producing data to meet these requirements until some time after 1992. The Army must, therefore, establish its most critical DTD needs (those that cannot wait for the new DMA system) and develop a cost effective method of producing this urgently needed data. To avoid needless duplication of effort, the Engineer Topographic Laboratories (ETL) must establish standards and specifications for the Army's interim terrain product needs and require that all new production efforts follow these standards. Annex E to this report discusses the current DTD deficiencies in detail, proposes an organization that should be charged with correcting these deficiencies, and estimates the professional staff years of effort (and dollar cost) that must be committed to solve the problem.

21. Off-line Analysis Addressing Engineer Task Effectiveness Will Be Required to Support Model Development. Before an engineer task can be successfully integrated into an AMIP model (including EFAM), supporting data will have to be developed. ESC recommends that each engineer task (see Annex F) be researched and analyzed using: historical data; results of field tests/exercises; and surveys of opinions from subject matter experts. Deficiencies in the available data necessary to support the modeling of engineer task effects should be identified and appropriate remedial actions taken. This is the area in which ESC intends to commit substantial effort during the next several years.

V. IMPLEMENTATION

22. EMIP Tasks. To effectively implement the recommendations cited in Section IV, ESC has established four separate programs: a CASTFOREM program, a combined EFAM-VIC program, a FORCEM program, and a DTD development program. ESC will manage the first three programs; ETL will manage the fourth program. The EFAM-VIC program will serve as the centerpiece for engineer modeling research and development and provide improved methodologies and data representations that can be exported to the CASTFOREM and FORCEM programs when appropriate. These three programs will be managed by a three-person ESC cell that has combat engineer modeling as its singular mission. Since the Army's need for interim DTD production encompasses a great deal more than just the modeling community, ESC has established a separate DTD production program. This program should be funded separately from the EMIP and managed by the Engineer Topographic Laboratories.

a. **The CASTFOREM program.** The desired engineer representation in CASTFOREM will be developed in two phases.

(1) Phase one. This is a continuation of a USAES effort which was initiated with TRAC-WSMR in May 1987 to measure the combat power of minefields. This study will result in an effective Engineer Module in CASTFOREM and, perhaps more important, will lead to a general recognition and acceptance by TRADOC users of the value of engineer representation to the overall model's effectiveness. This phase includes the addition of engineer activities associated with mines, antitank ditches, short gaps, and road craters. Although TRAC-WSMR has validated the new code and decision tables, it has yet to publish the results.

(2) Phase two. This phase would start after the completion of the first phase and would add WAM, dynamic delivery of mines by artillery or air, and obstacle combinations.

b. **The EFAM-VIC program.** This is by far the biggest EMIP effort and will provide the greatest pay-off in terms of support for engineer analyses. After independently analyzing the desired engineer representation in VIC (see Annex B) and the requirements specifications for an EFAM (see Annex D), ESC found that the two model improvement efforts have a lot in common. More precisely, if the engineer representation in VIC is enhanced

(per ESC's recommendations), the development program of an EFAM (using VIC as a basis) would be about 70 percent complete. Therefore, ESC has chosen to merge the two efforts into a single program as shown in Figure 4. All modifications to VIC will be implemented on a USACE R&D version of VIC before being offered to TRAC's reference version of VIC, the EFAM, or both. EFAM-VIC activities will be programmed as follows:

(1) VIC phase one. This phase initiates 14 improvements to VIC. The major thrust of this phase is to revise the method of representing engineer units and their capability in VIC. These improvements include not only the method of representation of engineer units, but also resource allocation and constraints, attrition, and effects of degradations on task performance. Accomplishing these improvements will provide a more flexible and realistic representation of engineer units and provide the framework for adding additional engineer tasks. Additionally, this phase starts the programming effort for many of the recommended countermobility, mobility, and survivability improvements in VIC. Finally, this phase also initiates the effort to coordinate changes to the "coordinated group move" logic, and adds the capability for air-delivered mines, maneuver units to use roads, and forward aviation engineer tasks.

(2) VIC phase two. The phase two work will complete VIC engineer representation in two areas. First, the foundation that began in phase one for incorporating a host of engineer tasks will provide a more complete set of engineer task effects for gaming in VIC. Second, a series of post-processor reports will be implemented to extract engineer task data from VIC that could be used for more detailed engineer analysis.

(3) VIC phase three. The phase three work will focus on the design and implementation of an internal decision process using the command and control structure and an analysis of the situation to generate new engineer jobs. With this structure in place, those engineer tasks which arise from the situation and are not a part of the input data will be fully implemented.

(4) VIC phase four. The phase four work will complete the representation of engineer tasks by adding those tasks which are dependent on the implementation of roads or which involve coordination outside of the engineer community.

EFAM DEVELOPMENT/VIC IMPROVEMENTS

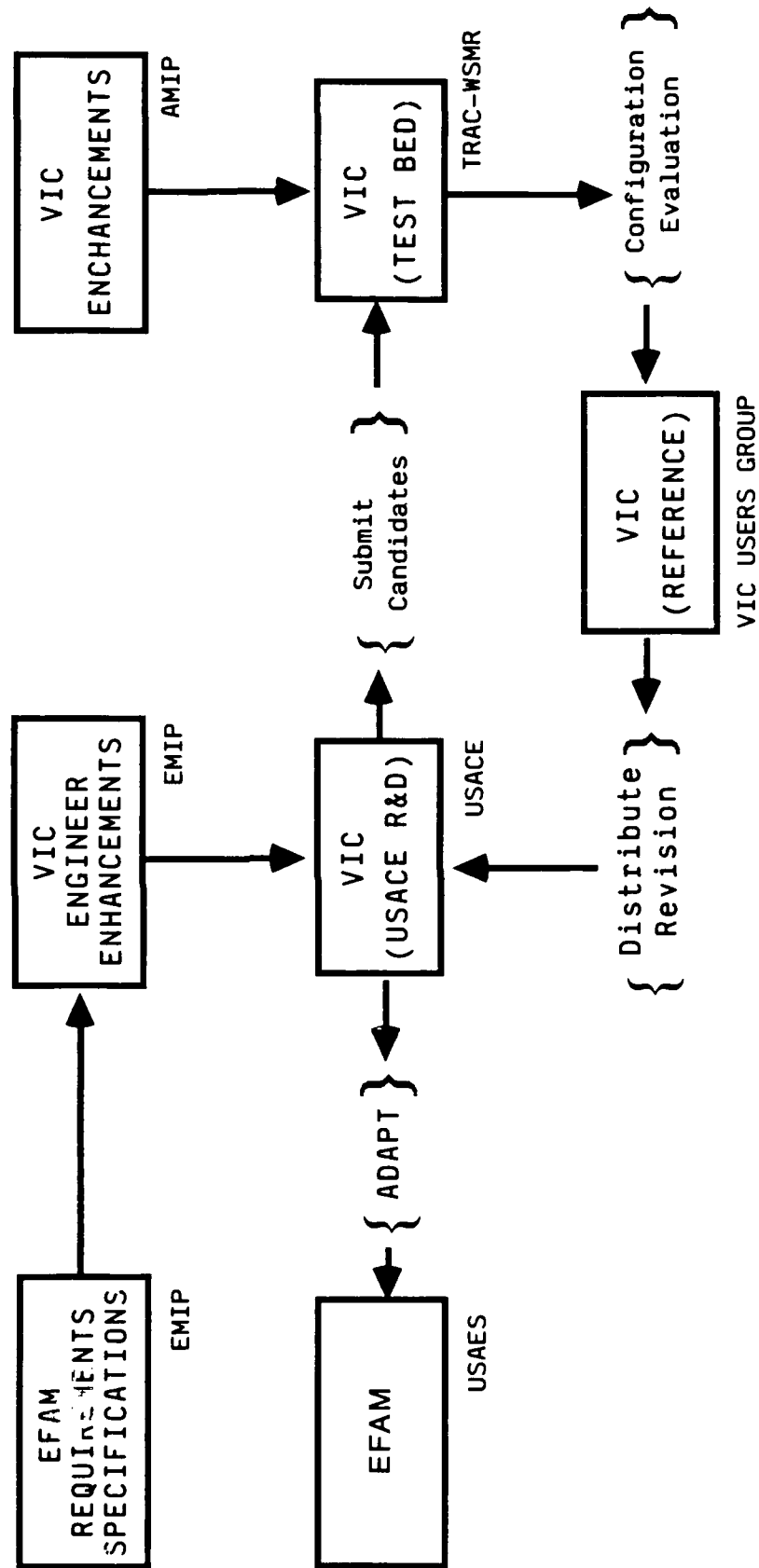


Figure 4

(5) EFAM additions. This phase will complete the representation of engineer tasks that are required in the EFAM, but not necessarily desirable for VIC. Predominant in this category are sustainment engineering tasks. In addition, the VIC structure will be modified to accommodate operation of the model in a requirements mode and additional post-processor reports.

(6) EFAM fielding. This phase consists of all the activities necessary to test, modify, and field a final version of the EFAM.

(7) Support activities. The following support activities will be performed concurrently with the above six phases:

(a) Data research. Tactical decision rules for executing engineer tasks will be defined, and data sets to support engineer modeling will be developed. The identification, collection, and validation of engineer-related data resulting from this research effort will also support model improvement efforts in CASTFOREM and FORCEM.

(b) Unit movement research. This activity will consist of basic research into the representation of unit movement in the VIC model. Deliverable products resulting from this research will include: changes to the "coordinated group move" logic; adding the capability for maneuver units to use roads; and improvements in terrain representation.

(c) R&D VIC maintenance. As previously mentioned, a single R&D version of VIC will be maintained by USACE. As the code is developed in support of the EFAM-VIC program, it will be implemented and tested on the USACE R&D VIC. This version of VIC will be fully operational and capable of serving as a prototype for EFAM.

c. **The FORCEM program.** To adequately represent the contribution of engineers in FORCEM requires a three-phase approach:

(1) Phase one. FORCEM would be modified to use division-level combat data from the planned engineer enhanced VIC.

(2) Phase two. Improvements would be made to FORCEM's representation of terrain, installations, and units.

(3) Phase three. Identified engineer tasks (see Annex C) and effects would be incorporated in FORCEM.

d. **The DTD program.** ETL should manage the production of interim DTD production by allocating the available resources in the order of priority

established by the ODCSINT and ODCSOPS. ESC's recommended priority order (based only on model requirements, not the more important tactical and C³I systems requirements) is given in Annex E. A program schedule and resource requirements based on ESC's recommendations are also outlined in Annex E. Based on the Army-wide importance of DTD to support systems in the field, this program should be considered separate from EMIP.

23. EMIP Schedule. ESC believes that EMIP must be aggressively pursued and completed in a timely manner. Extending the program over an indefinite period of time would be wasteful. The Army's efforts to modernize the total force have been and will continue to be expensive. Decisions concerning procurement must focus on systems that can demonstrate a high urgency of need and pay-off. The longer the engineer community delays in producing convincing engineer system requirements statements, the more likely they are of falling even further behind the rest of the Army. The same argument can be made for defending the engineer force in the Army force structuring process. Therefore, ESC has scheduled all EMIP activities to be completed within the next three fiscal years. Figure 5 shows the EMIP schedule subdivided by activity.

24. Resourcing EMIP. ESC estimates that the EMIP program shown in Figure 5 will require 27.5 professional staff years of effort, at a funding level of approximately \$3,585K.⁵ ESC has recommended a lead agency for each EMIP activity, in light of their areas of responsibility, experience, and capabilities. Any of these lead agencies may choose to seek contractor support. Recommended agency responsibilities are shown in Figure 6. Figures 7 and 8 summarize the EMIP resource requirements by organization and program, and by organization and year, respectively. For programming purposes, ESC is requesting that AMSAA, TRAC, CAA, and USAES provide a total of 8 professional staff years of effort on a non-reimbursable basis. USACE (CERL, ESC, and WES) will provide 19.5 professional staff years of effort on a cost sharing basis (approximately 70 percent USACE funded and 30 percent AMIP/USAES funded).

⁵Based mostly on cost estimates obtained from WES and CERL. When data was not available, ESC used a cost estimating relationship of \$10,000 per professional staff month of effort. This estimate includes approximately \$7,500 for personnel costs, \$1,000 for travel, and \$1,500 for other expenses (e.g., computer time, contractor support).

EMIP SCHEDULE & RESOURCE REQUIREMENTS*

	FY 89				FY 90				FY 91				FY 92			
<u>CASTFOREM</u>																
- Phase I	.5															
- Phase II					.5											
<u>EFAM-VIC</u>																
- VIC Phase I	.5															
- VIC Phase II		1														
- VIC Phase III			1													
- VIC Phase IV					1											
- EFAM Additions							1									
- Data Research	1.5				2											
- Unit Movement Research	2				1											
- R&D VIC Maintenance	2				2											
- EFAM Fielding									2							
<u>FORCEM</u>																
- Phase I					1											
- Phase II					2											
- Phase III									2							
<u>EMIP MANAGEMENT</u>	1.25				1.75				1.5							
TOTAL	9.25				12.25				5.5							

* NUMBERS REPRESENT PROFESSIONAL STAFF YEARS

Figure 5

RECOMMENDED AGENCY RESPONSIBILITY

	FY 89				FY 90				FY 91				FY 92			
<u>CASTFOREM</u>																
- Phase I	TRAC															
- Phase II																
<u>EFAM-VIC</u>																
- VIC Phase I	CERL															
- VIC Phase II		CERL														
- VIC Phase III			CERL													
- VIC Phase IV					CERL											
- EFAM Additions								CERL								
- Data Research					USAES			USAES								
- Unit Movement Research					WES			WES								
- R&D VIC Maintenance					WES			WES								
- EFAM Fielding									CERL							
<u>FORCEM</u>																
- Phase I								CAA								
- Phase II								CAA								
- Phase III									CERL							
<u>EMIP MANAGEMENT</u>																

TRAC
 CERL
 USAES
 WES
 CAA
 ESC

Figure 6

**PROFESSIONAL STAFF YEAR
ESTIMATES by MODEL**

AGENCY	CASTFOREM	EFAM-VIC	FORCEM	TOTAL
TRAC	0.5	1.0	-	1.5
AMSAA	-	0.5	-	0.5
CAA	-	-	3.0	3.0
USAES	0.5	2.0	0.5	3.0
USACE	0.5	16.0	3.0	19.5
TOTAL	1.5	19.5	6.5	27.5

Figure 7

**PROFESSIONAL STAFF YEAR
ESTIMATES by FY**

AGENCY	FY89	FY90	FY91	TOTAL
TRAC	0.75	0.75	-	1.50
AMSAA	0.25	0.25	-	0.50
CAA	-	3.00	-	3.00
USAES	1.00	1.00	1.00	3.00
USACE	7.75	7.25	4.50	19.5
TOTAL	9.75	12.25	5.50	27.5

Figure 8

25. Making EMIP Work. The EMIP is not a rigid program to be either implemented blindly or with rose-colored glasses. Rather, it is a strategy that is designed to guide engineer modeling improvements over the next few years. It is an engineer community plan, developed by ESC in conjunction with USAES, and supported by USACE. What we can learn from our past efforts in combat engineer modeling is that the engineer and the modeling communities must share objectives and be willing to work together as a team. Otherwise, the EMIP cannot be an effective program.

a. **EMIP update.** Beyond the first year, professional staff year and cost estimates for the EMIP are simply planning figures -- they must be continuously reviewed and revised. In addition, ESC developed this plan as a near-term fix to the most critical problems (i.e., the automated AMIP models). Once EMIP is underway (i.e., no later than FY90), ESC will refocus its attention to: the interactive analytical and training simulations; and the next generation of AMIP models (e.g., Conflict Model [CONMOD]). Future revisions of the EMIP plan will reflect these and other efforts.

b. **AMIP support.** EMIP has been designed to enrich the combat realism of the AMIP models. It is not intended to overburden any model with unnecessary detail. As such, ESC has carefully considered the impact of its recommendations on each specific model and feels that the recommended changes are appropriate and desirable to the Army community as a whole; not just the engineer community. USACE is willing to commit resources to EMIP, but USACE support alone is not enough. The AMIP community (i.e., AMMO, TRAC, CAA, AMSAA, USAES) has to feel that EMIP is worthwhile, and be willing to provide substantial support. Figure 9 shows the EMIP funding requirements for this comprehensive improvement program, and Figure 10 indicates the programmed and unprogrammed funding sources. ESC believes that full support of and implementation of the EMIP Plan is appropriate and clearly in the best interest of the US Army.

EMIP FUNDING REQUIREMENTS (\$K)

AGENCY	FY89	FY90	FY91	TOTAL
CERL	270	240	145	655
WES	595	505	410	1,510
ESC	190	250	220	660
DATA	240	320		560
TOTAL	1,295	1,315	775	3,385

Figure 9

EMIP FUNDING SOURCES (\$K)

FUNDING SOURCE	FY89	FY90	FY91	TOTAL
PROGRAMMED (USACE)	755	740	630	2,125
UNPROGRAMMED (AMIP / FAM-D)	440	475	45	960
(USAES)	100	100	100	300
TOTAL	1,295	1,315	775	3,385

Figure 10

LAST PAGE OF MAIN PAPER

ANNEX A

COMBINED ARMS AND SUPPORT TASK FORCE EVALUATION MODEL
(CASTFOREM)

ANNEX A

COMBINED ARMS AND SUPPORT TASK FORCE EVALUATION MODEL (CASTFOREM)

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I. INTRODUCTION

1. Purpose. This annex evaluates how effectively and appropriately combat engineers are represented in the Combined Arms and Support Task Force Evaluation Model (CASTFOREM), and suggests how the model's coverage of engineer activities can be enhanced.

2. Scope. This analysis:

- a. Presents an overview of the CASTFOREM environment and battle-field simulation.
- b. Examines the specific play of engineer units within the overall model.
- c. Provides a measure of the quality of current engineer representation.
- d. Provides some enhancements or modifications which should be addressed during future program development.

3. Limits. This annex is not offered as a users manual nor as the definitive source of information about CASTFOREM's military and modeling logic. Persons interested in a more in-depth presentation of the model's characteristics should consult the CASTFOREM documentation published by the Training and Doctrine Analysis Command at White Sands Missile Range (TRAC-WSMR), New Mexico.¹ The five volumes include: an overview of the CASTFOREM modeling logic; the interrelationships among the model's data files during the model runs; and an outline of the data variables and the structure of each of the data files.

a. This analysis examines the quality and enhancement of modeling logic within the CASTFOREM environment which treats combat engineer and engineer-like activities. Engineer-like activities are those that involve traditional engineer battlefield systems, but may not require the direct support of equipment and personnel from engineer combat support units. Examples of equipment used in engineer-like activities are aircraft- and artillery-delivered mines and tank-mounted counter-mine rollers and plows.

¹In five volumes, *CASTFOREM: Executive Summary*; *CASTFOREM: User Input Guide*; *CASTFOREM: Scenario Writers Guide*; *CASTFOREM: Post-processor Guide*; *CASTFOREM: Methodologies* (TRAC-WSMR, February 1988).

b. The ability of CASTFOREM to effectively model non-engineer systems, tactics, C³, and vehicle maneuvers is examined only as these issues affect combat engineer activities.

4. Background. CASTFOREM is a versatile, robust, high-resolution, two-sided, force-on-force, stochastic, systemic simulation model of a combined arms conflict. It enjoys universal acceptance within the modeling and TRADOC communities. The model simulates a fire-fight battle between a defender of battalion-size or smaller against an attacker of regimental-size or smaller. Whereas low-resolution models such as FORCEM simulate a conflict across an entire theater (600 by 600 kilometers) that may last up to 180 days and beyond, CASTFOREM simulates much smaller conflicts lasting, at most, 1-1/2 to 2 hours. The normal CASTFOREM battle area currently being played measures 20 kilometers by 20 kilometers and is graduated into 100-meter terrain cells.²

a. The model keeps detailed records of terrain features, individual vehicles, and weapons systems. CASTFOREM can even be configured to simulate the actions of individual soldiers. The model keeps an accounting of available and used projectiles, and of the flight characteristics and kill probabilities of each.

b. Because CASTFOREM is a stochastic model, several model runs of the same study scenario are required to eliminate aberrant combat results. Typically, TRAC-WSMR runs the model 12 to 20 times for each alternative situation postulated by a study. On a VAX 8800, the ratio of computer time to simulated battle time is approximately 2 to 1. The typical battle simulation lasts no more than 2 hours, resulting in a computer run of 4 hours per iteration.

c. CASTFOREM can currently simulate many engineer activities. Acquisition probabilities are degraded if target vehicles occupy protective fighting positions. The amount of degradation depends on whether the vehicle is in hull or turret defilade. Obstacles can be played explicitly. The location of mines within minefields and their effects against target vehicles

²Interview between ESC and Mr. A. Freeberg (Engineer Cell, TRAC-WSMR, 2 March 1988).

which attempt to force the minefield are modeled in detail. CASTFOREM also models the effect of breaching minefields and other obstacles.³

d. CASTFOREM was developed by the TRAC-WSMR in 1981. TRAC-WSMR maintains an official version of CASTFOREM, which they call the "floor" model. Because this version enjoys the approval of the Army modeling community, it is the only version used to support study requests that demand high-resolution modeling techniques.

e. CASTFOREM is used by the TRADOC community to evaluate, under wartime conditions, the combat characteristics of developmental hardware items for the Army. It is used to examine the effectiveness of specific tactical maneuvers against enemy weapons arrays. With CASTFOREM, it is possible to measure the battlefield contribution of such items as armored vehicles, weapons, and helicopters. It is also possible to evaluate emerging or current tactics and doctrine. Cost and Operational Effectiveness Analyses (COEAs) required by HQDA and HQ TRADOC for new equipment are supported by data derived from CASTFOREM. CASTFOREM is used to evaluate the operational effectiveness of integrated systems in the combined arms environment and to determine an optimum quantity and mix of system components in tactical combat organizations. CASTFOREM data are used to develop input data and decision tables for the Army's mid-resolution model, Vector-in-Commander (VIC), and low-resolution model, FORCEM.

f. TRAC-WSMR is the proponent for CASTFOREM and is responsible for CASTFOREM configuration control. The CASTFOREM program is written in SIMSCRIPT II.5. In addition to the floor version, TRAC-WSMR maintains a separate research and development (R&D) version of CASTFOREM. Agencies can request that the TRAC-WSMR staff add to or change the modeling logic of the R&D version to respond to a specific study question that cannot be answered using the floor version. They can also use the R&D version to test or validate newly developed code before recommending that they be included in the floor model. However, any changes to the floor model must have the approval of the TRADOC community.

³TRAC-WSMR recently revised the obstacle encounter section. The USAES is currently validating the decision tables which support this section through a 1988 countermobility study. (Also see paragraph 4h.)

g. In 1983, the TRADOC users began an extensive R&D effort designed to enhance the existing wargaming capabilities of the CASTFOREM. The US Army Engineer School (USAES) officially joined this effort in 1984 under the auspices of the CASTFOREM Engineer Modeling Feasibility Study. This R&D study tasked TRAC-WSMR to develop the code necessary to realistically portray battlefield obstacle and counter-obstacle activities. During the ensuing two to three years, the staff at TRAC-WSMR progressed from an R&D effort to an Army study support effort. TRAC-WSMR's transition to study support occurred as the enhanced version of the CASTFOREM gained acceptance within the TRADOC and modeling communities. Work on R&D efforts ceased as TRAC-WSMR assets were diverted to support the higher priority Army studies.

h. Representatives of the USAES say that because of higher study priorities at the TRAC-WSMR during past years, the school had been unable to obtain CASTFOREM staff support from TRAC-WSMR for the engineer obstacle/counter-obstacle R&D effort. Higher priority studies from the combat arms study community had filled the queue to capacity. The engineers, therefore, had little opportunity to influence the simulation characteristics. In May 1987, at the suggestion of TRAC-WSMR, USAES requested modeling support from TRADOC for a detailed countermobility study. The purpose of this study is fourfold:

(1) To measure a countermobility system's effectiveness and to quantify its effectiveness in terms of combat vehicle equivalents. That is, to try to answer questions such as, "How many combat vehicles is a minefield worth?"

(2) To add appropriate decision tables for countermobility systems and test CASTFOREM with these decision tables in place.

(3) To evaluate the simulation value of modeling minefields, other countermobility systems, and breaching systems. In other words, will the countermobility module add significant realism to the simulated combat? Will it do so at an acceptable cost in added computer run time?

(4) To convince the TRADOC modeling community that the updated countermobility module is a valuable analytic tool that should be included in TRADOC standard scenarios.

i. Other agencies that have copies of CASTFOREM are Harry Diamond Laboratories, US Army Missile Command, and the US Army Armament Research

Development Engineering Center. The Infantry School at Fort Benning, Georgia, also has its own version of CASTFOREM; it simulates dismounted infantry as well as vehicles. Although these agencies use their modified versions of the model for internal studies, the only model which enjoys official Army sanction is the floor model at TRAC-WSMR.

5. Approach. This analysis relies on information gleaned from documents and interviews.

a. The primary source was the five volumes of CASTFOREM documentation.⁴ Various briefing graphics supplemented these primary information sources.

b. ESC analysts interviewed representatives from the Simulation Support Division, TRAC-WSMR, and the Directorate of Combat Developments (DCD), USAES.

⁴CASTFOREM: *Executive Summary*; CASTFOREM: *User Input Guide*; CASTFOREM: *Scenario Writers Guide*; CASTFOREM: *Post-processor Guide*; CASTFOREM: *Methodologies* (TRAC-WSMR, February 1988).

II. DESCRIPTION OF THE MODEL

6. Simulated Terrain and Physical Environment. Terrain is represented by square cells. Normally, each cell represents a square of terrain measuring 100 meters by 100 meters although it is possible to use 50-meter, 25-meter, or even 12.5-meter cells. The use of the higher resolution terrain cells, however, incurs a substantial, often prohibitive, increase in model run time. Terrain considerations are covered in detail in Annex E.

a. Each terrain square is coded for:

- (1) Road surfaces
- (2) Surface features
- (3) Height of vegetation and built-up areas
- (4) Canopy concealment
- (5) Hydrography
- (6) Cross-country movement for dry conditions
- (7) Cross-country movement for wet conditions
- (8) Ground elevation
- (9) Obstacles

b. Movement within the battlefield is controlled through a system of user-established Movement-Control-Points (MCPs). An MCP is described by X-Y-Z coordinates which define a unique location on the battlefield. They are linked by the user to form networks simulating possible routes of march (flight) for maneuvering units.

(1) Ground vehicles are constrained by the mobility characteristics of the vehicle, the mobility limitations of the terrain over which the vehicle is attempting to maneuver, and their received orders.

(2) Helicopters are constrained by their inherent climb and descent rates, their straight and level flight rates, and also by their received orders.

c. Line-of-sight modeling considers both ground elevation and vegetation heights. The model degrades visibility for generator-induced combat obscuring agents. The CASTFOREM currently plays both vehicle-generated and artillery-delivered smoke.

d. Suppression of enemy movement and return fire by direct-fire and indirect-fire weapons are modeled through both generic decision tables and

special algorithms. CASTFOREM is flexible enough to accommodate emerging suppression techniques and effects.

e. Targets are acquired by either visual or laser devices. Visual acquisition depends on ambient light levels, observer movement, target background, and observer viewing time. The ability of laser devices to acquire targets depends on the amount of energy returned by the target.

f. Direct-fire engagements are explicitly modeled, fire system against fire system.

g. In CASTFOREM, the trajectory and the damage caused by artillery rounds or rockets are explicitly modeled. Normally, artillery units are implicitly prepositioned in static firing positions, most often located outside the confines of the battlefield mapped by the model. Although the model can track the projectiles of individual artillery tubes, support missions are usually fired as batteries, battalions, or regiments in order to minimize the modeling run times. Only those projectiles which land within the immediate vicinity of units are tracked by the model -- another modeling shortcut which reduces computer run time.

h. Helicopters are explicitly modeled in both their reconnaissance role and their direct-fire role. Helicopters can either acquire targets for themselves or for other weapons systems. In the case of laser-guided missiles, they can direct either their own missiles or those of another helicopter.

i. CASTFOREM emphasizes combat between vehicles and rarely plays dismounted infantry actions. Although the model is fully capable of playing individual soldiers, study proponents typically ask TRAC-WSMR to play only those infantry weapons systems that have a significant anti-armor or anti-vehicle impact, such as TOW and SAGGER missile systems. Even such prevalent anti-armor systems as LAWs, Dragons, and their Warsaw Pact counterparts are normally excluded from the CASTFOREM. The exclusion of dismounted infantry from model runs substantially decreases the computer run time.

j. CASTFOREM models communications between units. The communication can be perfect or it can be degraded to reflect a variety of combat or equipment limitations.

k. The effects of nuclear, biological, chemical (NBC) warfare are modeled implicitly by degrading acquisition times, hit probabilities,

communication times, and movement rates. Degradation rates are all specified by the user.

7. Units that Operate in this Environment. The size of the opposing forces modeled has no artificial limits. However, most model runs play one company-sized defender against a reinforced battalion. Because engagements are executed at the level of the individual weapon system, larger force structures resist successful analyses by generating overwhelming amounts of data.

a. CASTFOREM explicitly models the maneuver and engagement outcomes for individual:

- (1) Direct-fire ground weapons systems
- (2) Ground vehicles
- (3) Helicopters

b. CASTFOREM gives the user the flexibility of designing virtually any unit structure. Since the level of resolution is at the individual weapon system, unit composition is unlimited -- from an individual soldier with his weapon to a multi-vehicle force. The composition of the opposing forces is limited only by the size of the computer memory.

c. CASTFOREM provides the capability for modeling artillery supporting fires. The locations of artillery units, preplanned targets, and forward observers are usually established before the game run. During the run, the acquisition of targets is portrayed explicitly through decision tables.

8. Functional Processes or Operations Performed by the Units.

a. To support the activities of the various units being modeled, CASTFOREM also explicitly models through a variety of user-defined algorithms and decision tables:

(1) Command and communications. To perform actions, units must receive commands from higher authorities (from vehicle commanders up to regimental commanders). Units which observe something also must successfully communicate the discovery to others before such knowledge can be shared. The model can play a variety of radio types and mixes which are affected by battlefield conditions.

(2) Maneuver. Through command and decision tables, the computer moves units along predefined routes of march. The decision table format

accommodates dynamic changes of both routes and march formations by units faced with combat crises.

(3) Search for and acquire targets. Individual crew members of weapon systems search for and acquire targets. When predetermined conditions are satisfied by the crewman and his potential target, the crewman acquires the target.

(4) Engagement results. Engagements result in kills, damage, mobility kills, suppression of return fire or maneuver capability, or no effect. Engagement results are determined by the type of round; angle of attack; slope, thickness, and angle of the defensive armor; speed of the target; visibility; and speed of the firing platform.

(5) Requests for artillery fire support. Units can be programmed to call for artillery support when user-defined conditions are satisfied.

(6) Orders to fall back. Unlike some models in which units continue to fight until the last man is killed, CASTFOREM accommodates planned withdrawals. Decision tables can be developed which will call for the withdrawal of units when predefined conditions are satisfied.

b. CASTFOREM monitors ammunition and fuel expenditures. The model can also play rearming and refueling of units, although these options are rarely used. As alternatives to detailed modeling, units are either assumed to have unlimited ammunition and fuel or they are rearmed and refueled implicitly during movement between positions.

c. Although activation of supporting artillery fire and the accuracy and effect of the impacting rounds are modeled in great detail, the battery firing positions are normally plotted outside the boundaries of the battlefield terrain sector. Counter-battery engagements are not modeled, nor is artillery unit displacement.

III. ANALYSIS OF ENGINEER REPRESENTATION

9. Desired Level of CASTFOREM Engineer Play. An assessment of the level of engineer play appropriate for the model depends on what types of studies the model supports, the needs of the analytic community, and some measure of the relative impact of engineer activities on the other game components. CASTFOREM should play engineer combat with sufficient realism to support the combat development needs of the Engineer School. To this end, it must be detailed enough to discriminate between competing developmental material items. However, it must continue to support the study needs of the other service branches. The enhancements, therefore, should not be so detailed that the run time increases without a concurrent increase in gaming realism.

a. General. The increased number, acceptance, and availability of other high-resolution models have freed CASTFOREM from some of the higher-priority requirements which precluded access by the Engineer School.

(1) The countermobility study was initiated by USAES, at the suggestion of TRAC-WSMR, so that engineer modeling support could be incorporated into the TRAC-WSMR project schedule. The stated purpose of the study is to "analyze the effects and combat power that minefields provide in a combined arms conflict."⁵ Most of the remaining modeling time is used to support study requests from the combat branch schools (US Army Armor Center, US Army Infantry School, and US Army Field Artillery School), and the Combined Arms Center.

(2) CASTFOREM should respond to the analytic requirements of various TRADOC users. To be acceptable as an analytic tool, the model must reflect a realistic battlefield environment. The need for realism, however, must be balanced against the desire for reasonable model response time. If too much time is required to prepare the model's battlefield environment and decision tables, or if the new coding demands excessive amounts of computer run time, then the realism gained will be much less attractive to the analytic community. This is a particularly important consideration in the CASTFOREM

⁵*Project Coordination Sheet*, signed by COL F. Parker, US Army Engineer School (USAES), on 27 May 1987, and by Mr. H. McCoy, TRAC-WSMR, on 1 June 1987.

environment, because each study supported by the model requires from 12 to 20 separate runs of each study alternative scenario; and it is not uncommon to have as many as five such alternatives. (When using a stochastic model, multiple runs are essential to eliminate aberrant results from consideration.)

(3) The engineer task modeled must have a direct and measurable impact on the units or on other combat activities. The engineers must be able to complete the task within the span of time modeled by CASTFOREM -- no longer than 2 hours. CASTFOREM plays a short battle that precludes representation of a great many engineer tasks.

b. **Engineer forces.** The task force organizations played in CASTFOREM range in size up to battalion. The largest contingent of engineers which would typically be gamed is an engineer platoon. In addition to the six engineer vehicles, other non-engineer vehicles would be doing engineer-related activities (e.g., tank plows used to breach minefields). An average of about 15 vehicles would be affected directly by engineer and engineer-like task enhancements.

c. **Engineer tasks.** Engineer tasks are discussed in detail in Annex F. For the purposes of this analysis, only those tasks which have a direct, immediate, and local impact on local battalion task force combat operations are examined.

(1) **Counter mobility.**

(a) **Engineer emplacement of systems.** Reinforcing the terrain immediately to the front of defending units usually occurs several hours before contact by opposing forces. Most linear minefields, anti-tank ditches, and complex obstacle systems would be completed long before the beginning of the conflict depicted in CASTFOREM. Modeling the effort associated with emplacing 2,000 to 4,000 meters of obstacles and minefields needed for a company defense would increase the battle time by several hours or up to several days. The large time variance reflects the flexibility of the commander to allocate scarce engineer resources based on his battlefield priorities. Accommodating the play of engineer emplacement tasks is not a realistic goal for CASTFOREM managers.

(b) **Engineer weapons system activation.** The CASTFOREM modeling community should, however, consider enhancements to the model which would realistically portray the activation of dynamic counter mobility systems

such as RAAMS. The instantaneous creation of an anti-tank minefield on top of a maneuvering formation limits the maneuver commander to options different from those he would consider when faced with a pre-emplaced minefield to his front. Although similar to RAAMS in its means of delivery, the ADAM system, because of its anti-personnel nature, is not appropriate for modeling consideration. The MOPMS minefield package is usually activated before the arrival of enemy forces and, from a modeling standpoint, displays counter-mobility characteristics similar to those of a conventional minefield. Therefore, expenditure of effort to model the activation of the MOPMS system and the delivery of its minefield package is not appropriate. The question of whether or not to model the activation of the WAM anti-vehicle mine system depends on the characteristics of the system once developed and fielded.⁶

(c) Effects of the engineer system on vehicles and weapons systems. Detailed modeling of the effects of countermobility systems on an attacking force is critical to battlefield realism. Minefields, tank ditches, and other systems can be devastating to a well-orchestrated mobile assault by disrupting the integrity of the attacking formations and slowing the tempo of the attack. Commanders who fail to make breaching equipment readily accessible within their attacking formations will run the risk of additional losses. The model should consider such eventualities. Failure to consider these potential effects during combat modeling gives distorted combat results.

(2) Survivability.

(a) Engineer emplacement. Building fighting positions for weapons systems and protective positions for soft targets are engineer activities that occur well before opposing forces engage in combat. For this reason, modeling such activities is not appropriate for CASTFOREM.

(b) Effects of the positions on vehicles and weapons systems. The ability of a weapons crew to acquire and hit a target is directly affected by the existence or lack of protective positions. The advantages enjoyed by a force using good cover and concealment over a force in

⁶ADAM (Area Denial Artillery Munition) is an artillery-delivered, anti-personnel scatterable mine system. RAAMS (Remote Anti-Armor Mine System) is an artillery-delivered, anti-armor scatterable mine system. MOPMS (Modular Pack Mine System) is a command-initiated, scatterable mine system. WAM (Wide Angle Mine) is a sensor-initiated, anti-armor mine.

the open are well documented. Realistic wargaming, therefore, demands that the effect of survivability positions should be part of the CASTFOREM battle play.

(3) Mobility.

(a) Engineer construction. Engineer construction and repair of combat roads and trails and activities associated with forward aviation combat engineering are not appropriate for CASTFOREM modeling. These activities would occur well in advance of the time period modeled by the CASTFOREM and, therefore, should not be modeled.

(b) Effects on vehicles and weapons systems caused by having or not having engineer construction support. Adverse effects on combat units caused by the engineers' failure to complete these tasks occur after a substantial passage of time. Also, the effects tend to be felt more by the combat support and service support elements than directly by combat units; this makes quantitative measurement difficult. These effects, therefore, are not candidates for modeling.

(c) Counter-obstacle activities. Neutralizing the deleterious effect of obstacles on combat formations is an extremely important battlefield activity. Breaching minefields, walls, abatis, and obstacle fields; and traversing anti-tank ditches and small gaps are all battlefield activities that can occur within the boundaries of CASTFOREM's time frame. Both engineer forces and non-engineer maneuver elements play a role in breaching obstacles to movement. Assaulting formations are task organized with counter-obstacle needs in mind. An enhanced counter-obstacle module is essential to examine both the effectiveness of individual breaching systems and proper mix of breaching systems within the task force organization.

1. Breaching minefields. Because of the emphasis on mine warfare by modern armies, it is essential that CASTFOREM realistically model countermine activities.

2. Traversing anti-tank ditches. The need to quickly traverse anti-tank ditches and short gaps with launched bridging is prevalent on today's battlefield. CASTFOREM needs to accommodate these activities.

3. Breaching roadblocks and obstacle fields. Breaching roadblocks (e.g., craters and abatis) and obstacle fields are activities which are good candidates for CASTFOREM modeling.

(d) River crossing operations. Deliberate gap crossings and river crossings are not modeling candidates. There are two reasons for this. First, deliberate gap crossings are lengthy activities that usually require assistance from higher level engineer assets. Higher level engineer units are usually not depicted in the CASTFOREM environment. Second, these crossings are normally attempted only after both banks are secured by friendly forces or the far bank is held only by weak enemy forces.⁷ Incorporating a deliberate crossing would necessitate simulating airborne and air assaults and vehicle swimming and snorkeling capabilities -- this could represent a significant increase in model run time. Major gap crossing endeavors occur relatively infrequently. The infrequency strongly suggests that deliberate gap crossings should not be incorporated into the general usage CASTFOREM model. Modeling of such crossings would be more efficiently served through another model.

d. Summary.

(1) Figure A-1 shows the priority ranking of task categories for high-resolution models obtained from a survey of Army modelers, engineers, and maneuver commanders. The details of this survey are discussed in Annex F. Using this task ranking as a starting point, ESC developed Figure A-2 which is a list of tasks relevant to the CASTFOREM model. In some cases, specific tasks were added under the broad task categories of the survey (e.g., breach minefields under the category breach obstacles in the assault). In other cases, categories were dropped because they were beyond the scope of the short CASTFOREM battle time (e.g., improve assault breaches for follow-on forces). The second column of Figure A-2 shows whether the actual engineer task necessary to construct, emplace, breach, or traverse is a candidate for CASTFOREM enhancement. The third column shows whether the effects of the system should be incorporated into the CASTFOREM combat environment. For dynamic minefield systems, a fourth column shows whether the activation of the

⁷Mobility, FM 5-101 (Department of the Army, 1985), p. 6-14.

HIGH RESOLUTION MODELS -- OVERALL TASK RANKING

Task Categories Sorted In Priority Order	Priority Ranking (Percent)
<u>Vital Task Group</u>	
Prepare fighting positions for direct-fire systems	12.1
Install linear obstacles	11.1
Breach obstacles in the assault	10.8
Install point obstacles	10.0
Prepare positions for indirect-fire & other systems	9.1
Conduct river crossing operations in the assault	8.4
<u>Critical Task Group</u>	
Improve assault breaches for follow-on forces	5.7
Maintain main supply routes	5.7
Pioneer trail preparation & maintenance	5.3
Improve river crossing sites for follow-on forces	4.9
Forward airlanding facility preparation & maintenance	4.7
Site preparation & maintenance for CS & CSS units	4.5
<u>Essential Task Group</u>	
Rear area facility rehabilitation & maintenance	2.5
Airfield damage repair	2.2
<u>Necessary Task Group</u>	
Other (engineer raids)	1.6
Port & waterfront facilities construction & repair	1.0

Figure A-1

REQUIRED ENGINEER REPRESENTATION IN CASTFOREM

Engineer Task	CASTFOREM Should Model	
	Task	Effects
SURVIVABILITY		
Prepare fighting positions for direct-fire systems	-	X
Prepare positions for indirect-fire and other systems	-	X
MOBILITY		
Breach obstacles in the assault:		
-Breach minefields	X	X
-Breach obstacle fields	X	X
-Breach road craters	X	X
-Breach expedient obstacles	X	X
-Cross antitank ditches	X	X
-Cross short gaps with assault bridging	X	X
-Breach complex obstacles	X	X
Conduct river crossing operations in the assault	-	-
COUNTERMOBILITY (Pre-emplaced Systems)		
Install point obstacles:		
-Emplace point mines	-	X
-Crater roads and trails	-	X
Install linear obstacles:		
-Emplace a conventional minefield	-	X
-Emplace a GEMSS minefield	-	X
-Emplace a Volcano minefield	-	X
-Dig antitank ditches	-	X
-Emplace complex obstacles	-	X

Figure A-2 (Continued on Next Page)

REQUIRED ENGINEER REPRESENTATION IN CASTFOREM -- CONTINUED

COUNTERMOBILITY (Dynamic Systems)

Engineer Task	CASTFOREM Should Model		
	Task	Activation	Effects
Emplace minefield with:			
-RAAMS	N/A	X	X
-ADAMS	N/A	-	-
-MOPMS	-	X	X
-WAM	-	X	X

Figure A-2

mine dispenser or the delivery of the mines to the target area should be modeled.

10. Actual CASTFOREM Play. The level of engineer play now portrayed in the floor version of the CASTFOREM battleground falls slightly short of the desired level of play.

a. **Survivability**. The ability to acquire and hit targets occupying protective positions is modeled explicitly through direct computations. No further refinements to this category are needed.

b. **Counter mobility**. Currently, minefield patterns are generated randomly and the effects of individual mines are modeled explicitly through direct computations. The model can replicate the minefield patterns that might be expected from any of the current delivery systems. CASTFOREM uses decision tables to treat the breaching of other counter mobility systems (e.g., tank ditches and road craters).

c. **Mobility**. The breaching module clears from one to nine lanes through the minefield. The lanes may be cleared without benefit of specialized mine-clearing equipment. In addition, if the first vehicle in the file suffers a mobility kill, it is pushed aside by following vehicles. Since the following vehicles might actually go around the disabled one, the chance of detonating another mine would increase.

d. **Figure A-3** shows how the current floor version of the CASTFOREM plays engineer tasks and residual effects.

CURRENT LEVEL OF ENGINEER TASK REPRESENTATION IN CASTFOREM

Engineer Task	CASTFOREM Models	
	Task	Effects
SURVIVABILITY		
Prepare fighting positions for direct-fire systems	-	X
Prepare positions for indirect-fire and other systems	-	X
MOBILITY		
Breach obstacles in the assault:		
-Breach minefields	X	X
-Breach obstacle fields	X	X
-Breach road craters	X	X
-Breach expedient obstacles	X	X
-Cross antitank ditches	X	X
-Cross short gaps with assault bridging	X	X
-Breach complex obstacles	-	-
Conduct river crossing operations in the assault	X	X
COUNTERMOBILITY (Pre-emplaced Systems)		
Install point obstacles:		
-Emplace point mines	X	X
-Crater roads and trails	X	X
Install linear obstacles:		
-Emplace a conventional minefield	-	X
-Emplace a GEMSS minefield	-	X
-Emplace a Volcano minefield	-	-
-Dig antitank ditches	-	X
-Emplace complex obstacles	-	-

Figure A-3 (Continued on Next Page)

CURRENT LEVEL OF ENGINEER TASK REPRESENTATION IN CASTFOREM --
CONTINUED

COUNTERMOBILITY (Dynamic Systems)			
Engineer Task	CASTFOREM Models		
	Task	Activation	Effects
Emplace minefield with:			
-RAAMS	N/A	X	X
-ADAMS	N/A	-	-
-MOPMS	-	X	X
-WAM	-	-	-

Figure A-3

11. Desired CASTFOREM Play. Explicit modules will increase the run time but may provide a better modeling tool to evaluate system components. Implicit modules, on the other hand, usually are faster and may be sufficient if the performance of the system or the battle results are unlikely to be skewed by the lack of detailed computations. Another concern that surfaces when choosing between explicit and implicit modeling options is whether the operation of critical equipment components is modeled in the detail needed to discriminate between competing systems. Since CASTFOREM is used as a tool for such comparisons and to examine how such systems can be variously task organized to fit particular battlefield situations, the level of modeling detail is most important.

a. The modules which model minefields and antitank ditches can be triggered when a vehicle encounter occurs. If the terrain square containing the obstacle is never entered or if the unit chooses to bypass, it is sufficient to know only that an obstacle exists in the square -- detailed modeling is unnecessary. Once a unit undertakes a breaching operation, however, the pattern of obstacle components and mines, the boundaries of the obstacle field, and the operations of the breaching system should be modeled in detail. Antitank walls and wire obstacles need not be modeled. Walls are rarely a part of the defense and would not, therefore, be a critical impediment against

which vehicles and weapons systems should be measured. Wire obstacles have anti-personnel characteristics and serve little value in a wargame which plays only vehicles and weapons systems.

b. The delivery of dynamically delivered obstacle systems should be modeled if the delivery typically occurs in conjunction with vehicle against vehicle combat. The artillery delivered scatterable mine systems, for example, can deploy a minefield in the same location as that occupied by a military unit. The commander of the target unit is faced with a different set of problems than is the commander of a unit approaching a minefield. By-pass, for example, is an option that is unavailable to the first unit commander -- his unit is inside the minefield and he must breach his way out. On the other hand, if the delivery system fails to deliver the obstacle on target because of component failure or battle-induced errors, then the obstacle will have no effect on the target. Detailed modeling of both the delivery and the system effects is essential in this instance.

12. Required Modifications. As Figure A-3 shows, most of the engineer tasks are currently represented to the level of detail necessary to accurately portray their effects on the overall battle.⁸ Figure A-4 lists the engineer enhancements that must be represented for CASTFOREM to realistically portray battlefield conditions and provide a vehicle for examining engineer systems.

⁸Preliminary, unpublished results of the TRAC-WSMR test of the mobility and countermobility decision tables indicate that CASTFOREM accurately models the tasks shown in Figure A-3.

NEEDED ENGINEER ENHANCEMENTS TO CASTFOREM

Engineer Task	CASTFOREM Should Also Model	
	Task	Effects
SURVIVABILITY		
Prepare fighting positions for direct-fire systems	-	-
Prepare positions for indirect-fire and other systems	-	-
MOBILITY		
Breach obstacles in the assault:		
-Breach minefields	-	-
-Breach obstacle fields	-	-
-Breach road craters	-	-
-Breach expedient obstacles	-	-
-Cross antitank ditches	-	-
-Cross short gaps with assault bridging	-	-
-Breach complex obstacles	X	X
Conduct river crossing operations in the assault	-	-
COUNTERMOBILITY (Pre-emplaced Systems)		
Install point obstacles:		
-Emplace point mines	-	-
-Crater roads and trails	-	-
Install linear obstacles:		
-Emplace a conventional minefield	-	-
-Emplace a GEMSS minefield	-	-
-Emplace a Volcano minefield	-	X
-Dig antitank ditches	-	-
-Emplace complex obstacles	-	X

Figure A-4 (Continued on Next Page)

NEEDED ENGINEER ENHANCEMENTS TO CASTFOREM -- CONTINUED

COUNTERMOBILITY (Dynamic Systems)			
Engineer Task	CASTFOREM Should Also Model		
	Task	Activation	Effects
Emplace minefield with:			
-RAAMS	N/A	-	-
-ADAMS	N/A	-	-
-MOPMS	-	-	-
-WAM	-	X	X

Figure A-4

IV. ANALYSIS OF MODIFICATIONS

13. Modeling Approach. The decision to explicitly simulate a function within CASTFOREM must weigh the relative increased accuracy of the battlefield portrayal against a potential increase in model run time. The initial determination to choose an explicit simulation method over an implicit method is based on parameters that do not lend themselves to rigorous quantitative analysis. Any decision at this point must be based on intuitive reasoning. Once each new module has been developed enough to be incorporated into the R&D CASTFOREM, its relative merits can be measured by running CASTFOREM both with and without the module and comparing results.

a. As suggested in Figure A-4, the following engineer enhancements should be validated and incorporated into the floor version of CASTFOREM: (1) minefield patterns which result from conventional mine-laying techniques, dynamic mine-dispensing systems, Volcano, MOPMS, and GEMSS; (2) roller/plow, line charge, and force-through breaches of minefields; (3) anti-tank ditch and short gap crossings; (4) breaching road craters; and (5) overcoming combinations of obstacles. Developmental systems which are designed to have a direct and immediate effect on vehicles conducting assault operations, such as WAM, should be simulated explicitly as soon as an appropriate data base can be developed.

b. Figure A-5 suggests how accurate and realistic engineer representation can be developed in two phases. The first phase is a continuation of the USAES effort, initiated with TRAC-WSMR in May 1987, to measure the combat power of minefields. This study will result in an effective addition to the current simulation and, perhaps more important, will lead to a general recognition and acceptance by TRADOC users of the value of engineer representation to the overall model's effectiveness. This phase includes the addition of engineer activities associated with mines, antitank ditches, short gaps, and road craters. Although TRAC-WSMR has validated the new code and decision tables, it has yet to publish the results. The second phase should start when the first phase is complete and would add WAM, dynamic delivery of mines by artillery or air, and obstacle combinations. The engineer community should aggressively pursue modifications to the R&D CASTFOREM, with a view to

MODELING APPROACH -- CASTFOREM ENGINEER REPRESENTATION

Specific Activity	Specific Modeling Requirements
<u>Phase 1*</u>	
Minefield effects	Explicitly simulate patterns for minefields emplaced with conventional methods, Volcano, GEMSS, and MOPMS. Maintain the detailed computational module which plays different mine characteristics.
Minefield breaching	Explicitly simulate breaching minefields using force through, roller/plow, and line charges. Must allow for breaching multiple lanes through the obstacle.
Antitank ditch effects	Explicitly simulate rectangular-, triangular-, and sidehill-cut antitank ditches.
Antitank ditch breaching	Explicitly simulate crossing at several locations.
Short gap effects	Model the effects of gaps less than 18 meters wide using detailed modeling techniques.
Short gap crossing	Concentrate on modeling tactical bridging techniques such as vehicular-launched bridges and pre-fabricated air-transported bridging.
Road crater effects	The module should simulate craters of varying widths and depths emplaced by using either equipment or explosives.
Road crater breaching	The module should simulate force through breaching and breaching with the use of special equipment (e.g.: AVLB).

*Most of the effort in Phase 1 will be directed at validating modeling code and decision tables which are already in CASTFOREM.

Figure A-5 (Continued on Next Page)

MODELING APPROACH -- CASTFOREM ENGINEER REPRESENTATION -- CONTINUED

<u>Specific Activity</u>	<u>Specific Modeling Requirements</u>
Phase 2**	
Dynamic delivery of mines	Direct modeling techniques should be used to simulate the delivery of mines by artillery, air, or other methods onto an enemy force. Special consideration must be given to the enemy's reaction to a delivery of dynamic mines.
WAM effects	Stand-off, projectile delivery systems should be modeled explicitly. The module should play the activation of the firing mechanism as well as the flight and explosive characteristics of the projectile.
Obstacle combinations	The module should simulate various combinations of countermobility systems that can realistically occur within a 100 meter by 100 meter terrain cell (e.g. two parallel minefields and an antitank ditch seeded with mines).

**Phase 2 will require that some new coding and decision tables be created and that existing coding and decision tables be validated.

Figure A-5

incorporate successes into the floor version. Work on the various engineer modules must be scheduled in a manner that does not interfere with CASTFOREM studies initiated by USAES which support their combat development activities.

14. Ease of Modeling. USAES and TRAC-WSMR have developed the simulation logic, the coding, and the decision tables for a large part of the Engineer Module. Once the results are published for the countermobility study, USAES and TRAC-WSMR will have made substantial progress toward adequately representing engineers in CASTFOREM.

15. Resources Required. The engineer cell at TRAC-WSMR has both the experience and the modeling knowledge to provide adequate support to the

effort. Figure A-6 depicts the estimated professional staff years of effort that are required by TRAC-WSMR and USAES to complete the tasks within each phase.

MANPOWER REQUIREMENTS (Professional Staff Years)			
	WSMR	USAES	ESC
<u>Phase 1</u>			
Complete ongoing study for USAES, validate decision tables, and publish results.	0.25	0.25	0.25
<u>Phase 2</u>			
Develop coding for WAM, dynamic mine delivery, and obstacle combinations.	0.25	0.25	0.25

Figure A-6

16. Impact on Model. History suggests that engineer battlefield systems are significant factors influencing the outcome of the battle. It is reasonable to assert that, without adequate simulation of such engineer systems, CASTFOREM provides unrepresentative conflict results. CASTFOREM should reflect the results of a well-placed obstacle on a determined attacker who lacks sufficient breaching equipment.

a. Any additions to the current model are likely to increase its computer run time. It is incumbent on the engineer modeling community to insure that the increased run time is balanced by a requisite increase in combat realism. Otherwise, the engineer modules will not be used during future study runs and engineers will continue to be under-represented in this modeling arena.

b. The modeling community in general must not allow basic programming concerns such as requirements for additional coding, increased run times, and increased difficulty for scenario writers to drive the decision to add or

delete engineer modules. The key consideration must be whether the model enhancement measurably increases combat realism.

c. The enhancements currently under development to support the countermobility study do not appear to extend the R&D model run times to any significant degree. All of the Phase 1 enhancements use virtually the same modeling logic and coding. Their addition to the floor model should significantly increase combat realism at a small cost in increased run times.

LAST PAGE OF ANNEX A

ANNEX B

VECTOR-IN-COMMANDER (VIC)

ANNEX B

VECTOR-IN-COMMANDER (VIC)

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I. INTRODUCTION

1. Purpose. This annex analyzes the engineer representation of the Vector-in-Commander (VIC) Combat Simulation Model and recommends enhancements to it under the hierarchy of Army combat simulation models and the Army Model Improvement Program (AMIP).

2. Scope. This annex examines VIC in order to determine how to best improve its engineer representation. Recommended enhancements to the model are based on the model's intended use within the hierarchy of the Army's simulation models, the AMIP concept, and the resources needed to improve the model. This annex:

a. Describes the background, general characteristics, and use of VIC. This examination is based on VIC Reference (release) 1.0, including the Reference version 1.1 released in October 1987 and/or version 1.2 released in March 1988.

b. Analyzes the representation of engineer-related functions and tasks in VIC and compares it with the desired level of representation as the Army's mid-resolution, combat simulation model. Specific engineer-related data sets that have been used by studies using VIC are not examined. The terrain data used by VIC are analyzed in Annex E, "Terrain Data Base Analysis," of this report.

c. Identifies proposed improvements to VIC, describes the impacts associated with those improvements, and estimates the resources needed to implement them.

3. Model Background.

a. History of development. In 1982, TRADOC established a requirement for a corps-level model in which AirLand Battle Doctrine could be

represented and studied. The following modeling requirements for AirLand Battle were not available in the Army's existing models:

- Maneuver and fight in all directions
- Represent command and control staff function impacts on decisions
- Represent decision-making at different levels
- Represent the perceived situation for decision-making
- Employ electronic warfare systems
- Employ chemical and nuclear munitions
- Represent engineer functions, including mine-fields
- Represent recovery and return-to-duty of damaged vehicles

TRAC-WSMR (then called TRASANA) decided to take advantage of, and improve upon, the best features of existing models rather than to develop a completely new model. TRAC-WSMR selected the Vector-2 model (developed by Vector Research, Incorporated) for its representation of ground combat, and the USAF's Commander Model, which evolved from the Talon Model. The Commander Model had the advantage of a modular structure and the use of a modern simulation language, SIMSCRIPT II.5. Consequently, VIC was developed using the structure and language of the Commander Model (with some of its aspects of air combat) and a modification of the representation of ground combat from the Vector-2 Model. Over the three years of development of VIC and the resulting combination of placing Vector-2 attrition methodologies in the Commander Model structure, all modules were eventually revised or rewritten. In 1985, a review committee appointed by the Army Models Committee (AMC) selected VIC as the Army's corps/division-level model, and it was adopted into the Army's hierarchy of combat simulation models for analysis under AMIP in 1986, replacing the Corps/Division Evaluation Model (CORDIVEM) simulation.

b. **VIC configuration management.** As a result of the charter for configuration management of VIC, the VIC Model Proponent, TRAC-WSMR,

established the VIC Model Users Group (VMUG).¹ The first VMUG meeting was held in July 1987, and users having a requirement for the model were issued the Reference 1.0 version of VIC. VIC 1.1 was issued in October 1987 and VIC 1.2 was released in March 1988. According to the VIC charter, all holders of the model must abide with the configuration control policy. VIC users may modify their copy of the reference VIC, but when VIC results are used for briefings, analysis, or reports related to Army-sponsored studies, users must indicate the reference number and any changes made to the reference version of VIC. VIC users must compare new input/output against the reference version, clearly indicating the major differences. The charter also states that TRAC-WSMR will review and evaluate modifications to VIC and determine the modifications and enhancements to be included in new reference versions.

c. Use of VIC. Figure B-1 describes the studies that have used, or are using, VIC. This figure identifies the study, the performing agency, the time frame when the analysis was performed, the VIC release version used, and scenario used for the analysis. The first two studies performed with VIC used the pre-release 1.0 version. Although a minefield module was used for both of these studies, this version did not have the capability to model other engineer unit tasks that are in VIC Release 1.0. These other engineer tasks were modeled implicitly by the maneuver unit generating the requirement. All the studies performed with VIC since the introduction of Release 1.0 have used the Engineer Module, the Minefield Module, and the portions of the Terrain and Barriers Module that pertain to rivers and man-made linear obstacles. These studies have simulated about three to six days of combat. Figure B-1 also identifies the scenario used in each study because a study using a combat simulation model is conducted in two phases. The first phase involves the selection and modeling of a scenario. The second study phase introduces new parameters, or modifies existing data, to model the processes of particular interest in the study.

4. Method of Analysis. This analysis followed five steps:

a. First, analyze the operations that are modeled and data requirements of VIC. Study the overall model structure and characteristics of the

¹Charter for the Configuration Management of the Vector-in-Commander (VIC) Model (TRAC-WSMR, 3 April 1987).

STUDIES USING THE VIC MODEL

Study Name	Performing Agency	When Performed	VIC Release Used	Scenario Used
Battlefield 90	TRAC-WSMR	1984-1986	Pre-release 1.0	JOBAS III - South
Combined Arms Mission Area Analysis (CMAA)	TRAC-FLVN	1987	Pre-release 1.0	Europe 6.0
Armored Family of Vehicles (AFV)	TRAC-WSMR	1987	1.0	Europe 6.5
Forward Area Air Defense System (FAADS)	TRAC-WSMR	1987	1.0	Europe 6.5
Deep Fires	TRAC-WSMR	1987-1993	1.0	Europe 6.5
Close Combat Capability Analysis (CCCA)	TRAC-FLVN	1988	1.1/1.2	Europe 6.0/ 6.2

Figure B-1

various force component/capability modules. Develop a thorough understanding of VIC's representation of engineer units and engineer operations. This effort relied on the VIC documentation and interviews with the model developers and study managers using VIC.² The analysis of VIC documentation concentrated on six VIC modules (engineer, minefield, terrain and barriers, global ground, ground movement, and decision tables) because of their direct impact on this analysis.

b. Second (as a parallel effort), establish a baseline for adequate engineer representation in a mid-resolution ground combat simulation model such as VIC in the context of the Army's hierarchy of combat simulation models.

c. Third, assess the adequacy of VIC's engineer play by comparing its current capabilities with the baseline established in the second step.

d. Fourth, recommend actions to strengthen the engineer representation in VIC. This step also considers VIC's design objectives; past, current,

²VIC Model User Guide, draft documentation (TRAC-WSMR-TD, June 1987).

and projected uses of VIC in analytic studies; and the relative detail incorporated in the engineer representation compared to the detail afforded other force components and operations. This phase is based in part on a draft report by the US Army Construction Engineering Research Laboratory (CERL) which analyzed the engineer representation in VIC. That report was sponsored by the AMIP Management Office (AMMO).³

e. Fifth, analyze the impact of recommended improvements to VIC. Estimate the resources needed to implement those model enhancements and rank the improvements for incorporation into the model.

³*Analysis of the Engineer Representation in the Vector in Commander (VIC) Battle Simulation Model*, draft Technical Report (CERL, September 1987).

II. DESCRIPTION OF THE VIC MODEL

5. General.

a. VIC is a two-sided, deterministic computer simulation of combat in a combined arms environment. The model is designed to provide a balanced representation of the major force elements in a tactical campaign of a US Army corps operating in a theater of operations. It represents friendly air and land (blue) forces and a commensurate enemy (red) force in a mid-intensity battle. The model is event-stepped for maneuver elements and time-stepped for calculating support effects. The model can run in either an interruptible mode (for model development and scenario analysis) or in an automatic, batch mode (for study production runs). The model has a set of preprocessors for constructing input data files and a set of postprocessors for displaying model results. The VIC interactive preprocessors provide automated assistance for building or modifying the VIC force structure, deployment, and terrain database. VIC postprocessors are capable of graphics output displays of combat force locations. Eight postprocessors are available to process specific output data produced during a simulation. The main postprocessor is capable of displaying 26 tables of output data such as plots of the FEBA, unit locations, unit strengths, and mine assets. Other postprocessors produce tables for specific topics such as logistics, decision tables, and minefields.

b. VIC is designed to operate on the Digital Equipment Corporation (DEC) series of VAX computers (VAX 11/780 as a minimum, 8800 series is preferred) installed with the VMS operating system. The system configuration includes RAMTEK Corporation's color graphics 9460/65 system which is used for preprocessing and reviewing model output. The model is written in SIMSCRIPT II.5, and the preprocessor is written in ASCII FORTRAN. The model uses about 150,000 lines of code. The current run time can be about one hour of computer time for each three hours of simulated combat, but this ratio varies depending on computer equipment, the scenario modeled, and number of active modules.

6. VIC Model Purpose. According to AR 5-11, VIC is to be used for force design and concepts, doctrine, and tactics development for corps, divisions, or brigades. It will also be used for determining resource requirements for sustained operations and studying materiel and item systems

that are organic to, or have an influence on, the capabilities of corps, divisions, or brigades.⁴

7. Simulated Terrain and Physical Environment. VIC describes terrain in grid squares. There are no limitations on the size of the grid square, and the model user specifies its size. TRAC-WSMR and TRAC-FLVN both use a "4 km by 4 km" grid system. **Figure B-2** identifies the four major terrain factors in VIC. The number of terrain categories used within each factor is also user-dependent. Barriers and water obstacles (rivers and other streams) are represented by line segments which are independent of the grid squares. Roads form a linked, node network which are used only by logistic units. Although maneuver units do not take advantage of the logistic road network, permitting faster movement rates, their routes may correspond with the roads in the area. Trafficability and intervisibility parameters are associated with each grid square. Trafficability is a function of day/night, combat intensity, terrain, weather, and obstacles that are encountered on the path of a maneuver unit. Terrain and trafficability are integrated into a "combined trafficability index" which has three categories: good, fair, or poor. Visibility depends on the combined effects of day/night, weather, line of sight, and smoke. For a more detailed discussion of terrain, see Annex E, "Terrain Data Base Analysis." A weather cell is also defined over a grid area. Weather changes according to a predetermined weather chronology. Weather indices represent cloud cover and precipitation type. A VIC module for smoke allows maneuver and artillery units to disperse smoke that affects sensor target acquisition and direct fire battle.

8. Ground Force Deployments. **Figure B-3** identifies the unit types and unit levels that can be modeled in VIC. Although the size of any unit may be determined by the user, the normal level of resolution is battalion-level for the blue force and regimental-level for the red force. All ground elements that are considered individual units are located by either a two-dimensional coordinate or military UTM system. All independent ground elements initially move along assigned paths that represent avenues of approach or defensive

⁴Army Model Improvement Program, AR 5-11 (DA, 15 August 1983).

VIC TERRAIN FACTORS*

Vegetation

1. Dense forestation	3. Grasslands
2. Light vegetation	4. Urban areas

Relief

1. Plains	3. Mountains
2. Hills	

Area Obstacles**

1. Rivers	4. Urban areas
2. Passable features	5. NBC contaminated areas
3. Impassable features	

Linear Obstacles

1. Rivers	3. Tank ditches
2. Canals	4. Embankments (railway)

*The number of categories implemented under each terrain factor is user-dependent.

**This terrain factor is not used in the current release of VIC.

Figure B-2

zones. Second echelon or reserve units may change paths due to changes in the combat situation. Although the combined trafficability index has only three categories for each grid square, routes in VIC are developed from detailed map analysis and computer graphics displays of the terrain. For each node on each unit's path, there is an area defined that represents the area of influence or interest. This tactical area defines the portion of the battle area in which sensors assigned to the unit search for detections and the area from which targets are selected for supporting indirect fire systems.

9. Functional Processes Modeled. Figure B-4 identifies the roles and activities that maneuver units may play in the model. VIC is structured in 28 modules. Generally, each module maps into a major functional process on the battlefield. Figure B-5 identifies the individual modules and the functional processes modeled in VIC. The modeling of the operations plan is implied

VIC UNIT TYPES AND LEVELS

Unit Types

Tank unit	Missile artillery unit
Mechanized unit	Air defense unit
Infantry unit	Headquarters unit
Cavalry unit	Supply convoy unit
Attack helicopter unit	Forward supply area unit
Utility helicopter unit	Repair unit
Cargo helicopter unit	Airborne unit
Aviation HQ unit	Engineer unit
Artillery HQ unit	Intelligence unit
Tube artillery unit	Jamming unit
Rocket artillery unit	Electronic helicopter unit

Unit Levels

Front	Task force
Army	Company
Corps	Squadron
Division	Troop
Regiment	Battery
Brigade	Platoon
Battalion	

Figure B-3

MANEUVER UNIT ROLES AND ACTIVITIES

Maneuver Unit Roles

Covering force	Deep strike (airmobile)
Main battle area	First echelon
Reserve	Second echelon
Rear area security	

Maneuver Unit Activities

Defend	Counter-attack	Pass through lines
Delay	Advance	Reorganize
Withdraw	Pursue	Permanently retire
Attack	Move to reinforce	Bypass

Figure B-4

VIC MODULES AND FUNCTIONAL PROCESSES

VIC MODULES (with abbreviation)

System Specifications (SS)	Graphics Data Module (GX)
*Global Ground (GG)	Weather Data (WT)
*Ground Movement (GM)	*Terrain and Barriers (TB)
Artillery (AT)	*Decision Tables (DT)
Global Air (GA)	Helicopters (HC)
Air Maintenance (AM)	*Logistics (LO)
Air-to-Ground Attack (AG)	Communications (CO)
Air Intelligence (AI)	*Return-to-Duty (RD)
Ground Intelligence (GI)	Postprocessor (PT)
Fusion Intelligence (FI)	*Minefields (MF)
Air Defense (AD)	Air-to-Air (AA)
Defense Suppression (DS)	*Front Line Detailed Attrition (FL)
Electronic Warfare (EW)	Smoke (SM)
Chemical (CH)	*Engineer (EN)

VIC FUNCTIONS

Command and control	Smoke operations
Information processing	Support-fire operations
Intelligence and fusion processing	Attack-helicopter operations
Electronic warfare	Fixed-wing air operations
Maneuver-unit combat	Air-defense operations
Engineer operations	Combat service support

* VIC modules that are of particular interest for engineer representation.

Figure B-5

through the force organization, missions assigned to each unit, and the paths that represent the unit areas for movement and control. The following paragraphs briefly describe the purpose of the modules which influence the engineer representation in VIC.

a. The Terrain and Barriers Module provides the ability to simulate the impact of terrain and barriers (other than minefields) on combat forces. The key factors required for this module are vegetation, relief, and linear obstacles (e.g., rivers, embankments, canals, antitank ditches). These factors effect movement and visibility of maneuver units as they progress through the campaign area.

b. The Global Ground Module is one of the cornerstones of the VIC Model. This module provides the necessary data that defines the characteristics of all ground units, their initial locations, their initial maneuver plans, the size of deployment, and many other parameters which are necessary to define the land scenario. Many other modules tie in with this module.

c. The Ground Movement Module provides input data for ground movement, the command structure, and the areas of influence for those units which require them.

d. The Minefield Module represents the effects of minefield barriers in a land campaign. Other barrier types are addressed in the Terrain and Barriers Module. Minefields cause attrition and delay and limit movement.

e. The Engineer Module represents the various engineer-related activities that occur during a land campaign. VIC represents engineer tasks of divisional engineer units and higher echelon engineer units.

f. The Front Line Detailed Attrition Module handles the interactions of opposing front-line forces in a combat arena. The major conditions addressed in the module include unit combat roles and activities, the forces involved (personnel and weapon systems), environmental conditions (terrain, weather, and minefields), combat tactics, target acquisition and selection, and firepower and ammunition expenditure.

g. The Decision Table Module exercises control in the automated simulation. The method used in decision tables is a process of checking combinations of state variables at fixed or variable periods of time to determine a course of action. Generally, there are tables for each echelon and for every event that may be encountered by a maneuver unit during the campaign. Units continue to perform an activity until the decision table for that activity and unit level direct them to another activity. Decision tables consist of three basic ingredients: a set of conditions, a set of situations, and a set of actions. Whenever a decision table is accessed in VIC, the following sequence of actions takes place:

- Each condition specified in a table is checked to see if it applies. This defines the current situation.

- The set of conditions specified in the table are compared one-by-one to the current situation.
- When the first match is found, if any, then the set of actions related to the matched situation are performed.

In some decision tables, one of the specified actions may be to continue scanning the table. Also, one of the actions may be to consult another decision table if the specified action requires consideration by a higher echelon. The model has a library for "conditions" and "actions" as well as a library for the array of decision tables.

h. The Logistics Module and the Return-to-Duty Module represent the supply and support role of combat service support (CSS) with respect to ammunition, POL, subsistence or man-consumable supplies, maintenance support, field services, and personnel replacement.

10. Model Results (Output). The outcome of these force interactions is measured in terms of the ground gained or lost and the attrition of personnel and weapon systems. VIC uses postprocessors to describe the results of the simulation.

III. ANALYSIS OF ENGINEER REPRESENTATION

11. General.

a. Engineer units.

(1) Engineer units of any size can be gamed. Like other units which can independently maneuver on the ground, engineer units are identified in the Global Ground Module. Data regarding their work accomplishment rates and capabilities are supplied in the Engineer Module, and data regarding their detailed composition and equipment are provided in the Front Line Detailed Attrition Module.

(2) Only the lowest level engineer unit defined to VIC, usually modeled as a platoon, is actually able to perform engineering tasks. Units representing higher echelons are also modeled. Such a unit can be superior to any number of lower echelon units. The only purposes for superior level units are to arrange for reconstitution (personnel, equipment, and mines) of their lower level units, assign them missions, and control their movement.

(3) In VIC, when a superior level engineer unit moves, the lower level units must also move in such a way that their offset (while not performing a mission) from the superior is maintained. If a lower level unit is performing a mission consisting of several tasks at different locations at the time of the move, it completes work on all tasks in the mission prior to moving. VIC creates a path for the movement of the subordinate engineer units. Unlike maneuver units undergoing a "coordinated group move," engineer units are subject to the effects of terrain and barriers as they move.

b. Engineer unit capabilities. Figure B-6 provides an overview of the engineer tasks modeled in VIC, whether gamed as a capability of the engineer unit, individual non-engineer units, or both. Engineer units at the lowest level (the only units which can do work) must be one of four types. Each type can accomplish only one type of work. The four unit types are minefield teams (emplacement only), linear obstacle teams (emplacement only), bridging teams, and survivability teams (defensive position construction). Subsequent paragraphs provide more detail on how VIC models these tasks.

c. Engineer task assignment and ranking.

(1) Tasks for engineer units can be specified in the VIC model's input data. In the Minefield Module and the Terrain and Barriers

VIC ENGINEER TASKS¹

Functional Area	Task	Results	Capability of:	
			Non-engineer Unit?	Engineer Unit?
Countermobility:				
	Install minefields ²	Enemy delay, attrition	Yes ³	Yes
	Install linear obstacles	Enemy delay	No	Yes
Mobility:				
	Breach minefields	Friendly delay, reduced attrition, improved mobility	Yes	No ⁴
	Breach linear obstacles	Friendly delay, improved mobility	Yes	No ⁴
	Breach linear obstacles with bridging	Friendly delay, improved mobility	No	Yes
Survivability:				
	Prepare defensive positions	Reduced friendly attrition	Yes	Yes

¹All tasks take time to perform. An engineer unit performing a task is unavailable for simultaneous work elsewhere. Engineer equipment is not explicitly modeled.

²If the Logistics Module is played, this task can explicitly require the availability of mines.

³Artillery can emplace a minefield using FASCAM munitions.

⁴Engineer unit capability is identical to that of non-engineer units. Engineer units cannot be tasked to perform this mission.

Figure B-6

Module, input data can specify a site where a minefield or linear obstacle is to be emplaced at some future time. This task is placed in the engineer task list by task type and force (Red or Blue) and becomes an active request when a defending maneuver unit supported by an engineer unit is within a user-specified range of the FEBA.

(2) *When the task is accomplished* depends on resource availability (engineer units and, if logistics is played, mine availability). The model user, via input data, controls how tasks are grouped into missions based on geographic location of the task site (offset from the FEBA and tactical area) and unit munitions-carrying capability. Whenever possible, the engineer units are to accomplish all tasks in the mission before returning to their base for resupply, movement, and subsequent tasking.

(3) Once requests for emplacement of a minefield or linear obstacle become active, they are ranked by proximity to the FEBA. A minimum and maximum offset must exist before engineers will attempt the task. Within that user-specified range of distance from the FEBA, tasks closest to the FEBA will be attempted first. If, during task work, the FEBA trace moves to a distance less than the minimum offset, the engineer unit will stop work on the task and abort the current mission. A minefield that is partially completed is ineffective; the effectiveness of a partially-completed linear obstacle is proportional to the time spent constructing the obstacle before aborting the mission.

(4) Survivability position construction tasks are scheduled in much the same way as minefield and linear obstacle emplacement tasks except that the input data does not permit a time at which the sites are to be prepared. Thus, task generation is more dynamic. The various path points through which a maneuver unit passes are designated in the input data as either needing or not needing preparation. The proximity to the FEBA dictates task priorities.

(5) Engineer bridge team assistance is requested dynamically by a maneuver unit when they encounter a river or other linear obstacle which has been specified by input data in the Terrain and Barriers Module as requiring a breach with bridging. Engineer breaching support is performed in the order requested.

d. **Task accomplishment.**

(1) Task accomplishment consists of several processes, each requiring time. These include return to engineer base (i.e., to the next superior-level unit) and replenish, move as a result of superior engineer unit move, receive next mission (actually a set of tasks), travel to first task site, set up, perform task, travel to next task site, etc. During any of these processes, the engineer units can be delayed and constrained by artillery and air activity, munitions availability, user-specified work accomplishment rates, and the length of time they can work without an enforced rest period.

(2) Although VIC is capable of attrition, engineers have typically not suffered from these effects in past studies. Engineer attrition in VIC involves three elements. First, engineer units must be classified as opponents which interact with opposing forces. Second, "engineer systems" must be classified as targets for attack. Third, direct-fire attrition can occur only if the minimum FEBA offset for engineer units performing tasks is set to less than the range of direct fire weapons.

12. Counter mobility.

a. **General.** VIC models engineer unit operations of emplacing minefields and constructing linear obstacles. VIC does not model point obstacles; however, VIC's method of treating linear obstacles makes it possible to attain a degree of point obstacle representation by modeling it as a short linear obstacle. VIC does not model main supply route (MSR) interdiction techniques, such as bridge demolition, but it does model the destruction of tactical bridges by friendly units in retrograde. This latter task is implicitly modeled; there is no time penalty associated with "undoing" the breach.

b. **Minefields.** VIC provides flexibility to the model user in minefield specification, emplacement means, and activation. Figure B-7 lists the major minefield characteristics that VIC supports.

(1) Minefields can be any of several user-specified generic types, each with its own characteristics of lethality to various weapon prototypes, delay due to discovery, breach, negotiation, and minefield

MINEFIELDS IN VIC

Minefield Types:

Anti-armor, Anti-personnel, or both.
Directed, conventional, or scatterable.

Emplacement Options:

Pre-existing: Minefield locations can exist at the beginning of the simulation. Mines for these minefields can be already emplaced and active, or they can be emplaced and "fuzed" to become active at a specified later time. For both of these cases, it is possible to specify a "defuze" time when the minefield is deactivated.

Engineer unit emplacements: It is also possible to specify a location as a potential minefield site which can be automatically selected for minefield emplacement by an engineer minefield team when certain conditions (in Decision Tables) are met. It is also possible to construct an engineer mission to install the minefield through the Decision Table logic. Engineer unit equipment, such as a GEMSS dispenser, is not explicitly modeled. However, the Engineer Module can specify implicitly manual or equipment-assisted dispensing through input data.

Artillery-delivered emplacements: It is possible for a maneuver unit to dynamically request a FASCAM minefield from an artillery unit as a result of a tactical decision rule. VIC determines the location and all other attributes for this minefield.

Physical Attributes:

The following minefield characteristics can be specified in the Minefield Module: number of mines, minefield frontage, minefield depth, orientation (degrees), UTM coordinates of the minefield center, and several attributes that determine the outcome when a maneuver unit encounters the minefield.

Figure B-7

clearing fraction associated with crossing tactic. It is possible to overlay multiple minefield types.*

(2) The input data for the Minefield Module also contains the minefield mission numbers that control which minefield laying tasks will be grouped into a minefield team mission. The order in which the missions are selected is a function of distance from the FEBA.

(3) If the FEBA moves in such a way that engineer units are threatened (the distance decreases to the minimum offset value specified in the input data), the unit will stop working on the current task and abort the mission. In this case, the minefields that were totally completed on the mission would be effective; the partially- and to-be-completed minefields in the mission would be ineffective.

(4) Only an engineer minefield team (and artillery units firing FASCAM munitions) may be tasked to emplace a minefield. To perform the engineer mission, VIC logic selects the first available team that is supporting the unit (tactical area).

(5) Artillery-delivered FASCAM may be requested by maneuver units in areas where minefields were not preplanned.

c. **Linear obstacles.**

(1) Linear obstacles (e.g., rivers, embankments, canals, antitank ditches) are defined by VIC in the Terrain and Barriers Module. They can be initially active or inactive. If inactive, they can be activated later by an engineer linear obstacle team. Linear obstacles are composed of a user-specified number of line segments. Each segment of the obstacle can have unique delaying characteristics assigned by the user. There is no current way to assign attrition characteristics to linear obstacles. However, combat multiplier effects are represented because of the greater attrition that occurs from covering fire as the unit is delayed while breaching the obstacle.

*While it is possible to overlay multiple minefield types, it is important to note that overlaying minefields does not necessarily provide combined effects for units encountering these minefields. VIC processes a single minefield at a time and physically "jumps" a unit over a minefield after the proper delay has been assessed. If a second minefield is totally contained in the first, or has its center within the first, the unit will not encounter the second minefield because of the jump.

(2) Obstacles are encountered by any maneuver unit traversing a path that crosses an obstacle line segment. The obstacle line segments themselves are defined with starting and ending coordinates. The length of these line segments is independent of the VIC grid square terrain representation. It is possible to specify that one or more of the line segments composing the linear obstacle are already breached at the start of model play.

(3) Delay times due to barrier encounters can be separately specified for breached and unbreached conditions and for the force (Red or Blue) encountering the obstacle. Input data can also specify whether any particular obstacle line segment requires bridging in order to be breached, or whether it has already been breached.

(4) Engineer team emplacement of a linear obstacle is accomplished in a manner similar to the emplacement of a minefield. The mission numbers are contained in the Terrain and Barriers Module.

13. Mobility.

a. Engineer unit mobility tasks.

(1) The only VIC engineer unit capable of performing a mobility task is the bridge team. This capability can be used to cross a river or other linear obstacle, such as a dry gap. Bridge equipment is not explicitly modeled.

(2) Other mobility functions played in VIC are implicitly the responsibility of maneuver units. Even bridging operations can be implicitly performed by a maneuver unit when engineer assistance is unavailable.

(3) VIC does not currently model engineer mobility tasks related to the construction, maintenance, and repair of MSRs. Rear area MSRs are explicitly introduced into the model in the Logistics Module and are used only for the transport of supplies and damaged/repared equipment -- not for maneuver unit operations. While attrition of logistics units conducting resupply operations along an MSR is played, degradation and interdiction of the MSR itself is not modeled.

(4) VIC also does not play breaching of survivability or heavily fortified positions. VIC does not model a breach of a point obstacle, and it does not generate requirements for pioneer trail construction, maintenance, or repair.

b. Effects of minefields on maneuver unit operations.

(1) A maneuver unit will encounter a minefield whenever its straight line traverse between two path points intersects an active minefield. The minefield's location is not bound by the terrain grid square limitations. When a maneuver unit encounters a minefield, the input data for the minefield is referenced to see what type of minefield it is. If it is a "directed minefield," then attrition and delay amounts are immediately applied and the minefield is considered cleared and removed from the list of active minefields.

(2) If a conventional or scatterable minefield that has not been previously discovered is encountered, then attrition and delay are applied according to constants supplied in the input data. This is called a "discovery" loss. Next, an additional delay is assessed representing the time it takes for the unit commander to decide the minefield tactic to be employed (breach, bull, or bypass).

(a) The breach option is modeled to represent a deliberate breach. There are attrition and delay effects associated with this tactic. The deliberate breach is implicitly assumed to be accomplished with organic resources, but any breaching equipment actually available to the unit does not enter into the calculation of breach time. The breach time is a function of the type of minefield, and its density, frontage, and depth.

(b) The bull option is modeled as a hasty breach with attendant increased attrition and reduced delay effects as compared with the deliberate breach.

(c) The bypass option consists of a delay with no attrition except for that resulting from fires the unit may already be receiving. At the end of the delay period, the unit is relocated to the other side of the minefield. This method of processing enables a bypass tactic selection even when a bypass route is actually not available.

(d) The specific tactic to be employed is selected through the Ground Combat Status Mapping Table in the Global Ground Module. The selection is based only on the combat status of the unit.

(3) The next effect of the minefield is an attrition and delay associated with actual negotiation of the minefield (for breach and bull tactics only). The delay and attrition factors are controlled by the model

user via the input data. Attrition effects can be specified to weapon prototype detail, if desired. The negotiation attrition is assessed *at the end* of the negotiation delay period. The timing of the minefield attrition is significant. The net effect is that while the unit is engaged in combat and simultaneously negotiating the minefield, they are fighting at a strength which does not take into account the attrition effects of the minefield.

(4) The combat-multiplier effect of a minefield is modeled by the additional delay imposed on the unit as it negotiates the minefield. This increases the unit's losses from direct/indirect fire as it enters the minefield. There are no routines currently implemented via decision tables that create a request for indirect fire upon an enemy unit detected entering a minefield.

(5) For minefields that have been previously discovered, there are two primary differences from the description provided in paragraphs (1) through (4) above. First, there is no delay and attrition assessed as a discovery loss. Second, prior breach and/or bull activity has reduced the minefield effectiveness by prescribed amounts. Attrition and delay effects are linearly dependent on the fraction of remaining minefield effectiveness. After the minefield effectiveness is reduced to an input-data-prescribed fraction of its original value, the minefield is considered to be totally ineffective and is removed from the list of active minefields.

(6) Another factor affecting unit attrition from a minefield is the combat status (i.e., engaged or not engaged in combat) of the unit as it enters the minefield. VIC normally models units as being deployed in a circle with equipment and personnel deployed within that circle into the front, rear, and flanks. However, when a maneuver unit encounters a minefield, VIC also looks at the unit deployment in terms of columns. The unit formation (controlled by input data) will normally spread out and use more columns if the unit is engaged. Thus, if the minefield frontage is less than the width of the deployed unit, then the fraction of the unit entering the minefield will be smaller when the unit is engaged.

c. Effects of linear obstacles on maneuver unit operations.

(1) Like minefields, a maneuver unit will encounter a linear obstacle whenever its straight line traverse between two path points intersects an active obstacle. Units cannot bypass a linear obstacle in VIC,

however. When a maneuver unit encounters a linear obstacle, they are delayed a set amount of time. This time is dependent on whether the obstacle has already been breached and whether the side encountering the obstacle is Red or Blue. The actual delay constants are specified in the input data for each individual generic linear obstacle. As many generic types as desired may be input. The maneuver unit conducts the breach using resources implicitly assumed to be available.

(2) If the obstacle is a river or a gap that requires a bridge for breaching, then the maneuver unit's actions are different. Upon encountering such an obstacle, the maneuver unit will immediately request assistance from an engineer bridge team. In the meantime, it "begins" work to breach the obstacle itself. It does not need to have a bridge to do this work; it simply requires the amount of time specified in the input data of the Terrain and Barriers Module. If the engineer unit never arrives, it is still possible for the maneuver unit to complete the breach.* If the engineer unit arrives, the breach time is reduced by taking into account the work the maneuver unit had already completed.

(3) At present, if a maneuver unit encounters one of the line segments composing a linear obstacle, it is not possible in VIC for the unit to determine if a nearby line segment composing the total obstacle has already been breached. It may, in reality, be more expedient for the unit to bypass the obstacle using a breach already created. Also, VIC does not currently model the creation of several breach positions (multiple bridges) on the same obstacle line segment.

14. Survivability.

a. Armor and infantry survivability positions.

(1) VIC models the use of engineer teams to construct survivability positions. All path points requiring preparation of positions are specified in input data. These data associate a prepared/unprepared condition (ranging in value from 1.0 to 0.0) with these path points. This condition is used to modify loss rates in direct fire exchanges and to modify the portion of the unit exposed to air and artillery barrages. The kill rates used in VIC

*The input data that portrays the linear obstacle controls the time for a maneuver-unit breach. If maneuver units are incapable of breaching the obstacle, its unassisted breach time should be set to a large number (infinity).

assume that some advantage of natural cover has been taken even for unprepared positions.

(2) Engineer survivability teams simply work on the path point requiring positions in the tactical area which is closest (but not too close) to the FEBA. Therefore, it is possible that a point which is closest to the FEBA, but has no unit moving to it, is prepared before a path point which is further from the FEBA and has unit moving to it for cover.

(3) Maneuver units also have a user-specified capability to prepare positions for themselves. The time to complete that activity can be input for each maneuver unit prototype defined to VIC. Whether preparation is performed by engineers or the maneuver unit itself, a partially completed job provides partially improved protection.

b. **Artillery and rear area survivability positions.** Artillery units and units in the corps rear areas do not currently have the capability to request engineer unit assistance for preparing defensive or protective positions.

15. Sustainment Engineering. VIC does not presently model any sustainment engineering tasks.

16. Topographic Engineering and Fighting as Infantry. VIC does not currently model any of the engineer tasks associated with topographic support and engineers fighting as infantry.

IV. COMPARISON WITH DESIRED LEVEL OF ENGINEER REPRESENTATION

17. Desired Level of Engineer Representation. The level of engineer representation in VIC should depend on the model purpose (the types of studies the model supports), and the needs of the analytic community. This representation must have an impact on the other functions modeled in VIC, and it should also maintain a balanced representation with them.

a. VIC purpose and use. VIC's purpose is to simulate a mid-intensity battle of opposing forces up to a US Army corps in order to analytically estimate net assessments, perform force deployment studies, or generate information for performing trade-offs among weapon systems. TRAC is the primary user of the VIC model. Figure B-8 describes the purposes of TRAC studies that have been conducted using VIC. According to the AMIP Management Office, there are over 100 potential studies that could be conducted using VIC, but only a few of these studies are assigned a TRADOC priority high enough to be conducted on VIC by TRAC each year. Engineer-specific studies do not have a priority high enough to be conducted by TRAC using VIC.⁵ Therefore, the engineer representation in VIC should have, as a minimum, sufficient detail and fidelity to ensure that model results are reasonable and adequate for the specific VIC applications (primarily non-engineer studies).

b. Desired engineer representation in VIC. Because VIC is the Army's mid-resolution, corps/division simulation model, this model should, as a minimum, represent the effects resulting from the execution (or non-execution) of engineer tasks that are performed forward of the corps rear boundary (either explicitly or implicitly). Figure B-9 identifies those tasks by engineer functional areas.* Four engineer tasks (rear area facilities rehabilitation and maintenance, airfield damage repair, port and waterfront facilities construction and repair, and other) described in Annex F were not included in Figure B-9 because the tasks are normally performed behind the corps rear boundary. Additionally, these four tasks are not as important

⁵TRADOC memorandum (ATRC-RPP), Subject: FY 88 TRADOC AR 5-5 Study Program, 29 October 1987.

*See Annex F, "Engineer Task Analysis," for more details on the selection of engineer tasks in a mid-resolution combat simulation model.

VIC STUDY PURPOSES

Battlefield 90: A joint German-US, corps-level investigation of a Warsaw Pact invasion, including the effects of minefield attrition on the enemy force.

Combined Arms MAA: To investigate the relative importance of improving various force capabilities. Focus was on combat-heavy components and their division/corps support functions.

Armored Family of Vehicles: To investigate the Army's light, medium, and heavy vehicles used in a stand-alone or weapons platform mode. The three cases were the current vehicle, upgraded current vehicle, and new vehicle (with interchangeable parts).

Forward Area Air Defense System: To examine the sensitivity of VIC to changes in Air Defense structures and the contribution of air defense artillery to the corps battle.

Deep Fires: To investigate the mix and quantity of delivery vehicles and munitions that satisfy the Army's requirements for attacking the enemy deep under AirLand Battle.

Close Combat Capability Analysis: To perform a Close Combat-Heavy and Close Combat-Light MAA. To determine the force components with the greatest effect on the battlefield and the effectiveness of improvements to the capabilities of a given force component.

Figure B-8

(tasks have a lower priority for engineer execution) as the other tasks in a corps/division-level model.

18. Comparison with VIC Model.

a. Current level of representation. Figure B-10 summarizes VIC's current representation of engineer tasks. For ease of comparison with VIC, linear obstacles are further separated into the categories of minefields, other linear obstacles, and complex obstacles. Complex obstacles are combinations of minefields and/or linear obstacles. Engineer-related tasks can be performed by both engineer and non-engineer units. Engineer unit capability resides in four teams (minefield, linear obstacle, bridging, and survivability). While VIC does account for unit-allocated equipment and has the capability to attrit specific classes of equipment, the availability and capability of that equipment does not affect engineer unit work accomplishment rates.

DESIRED ENGINEER TASKS FOR VIC

Countermobility

Install linear obstacles (conventional and scatterable minefields, other linear obstacles, complex obstacles)*
Install point obstacles*

Mobility

Breach obstacles in the assault
Improve assault breaches for follow-on forces
Conduct river crossing operations in the assault (tactical bridging)
Improve river crossing sites for follow-on forces (fixed bridging)
Prepare and maintain pioneer trails
Prepare and maintain forward airlanding facilities

Survivability

Prepare fighting positions for direct fire systems
Prepare positions for indirect fire and other systems

Sustainment Engineering

Maintain main supply routes (roads)
Prepare and maintain sites for combat support (CS) and combat service support (CSS) units

Topographic Engineering and Fighting as Infantry

None

*Should also allow synergistic effect of obstacles with direct and indirect fires (attrition rates).

Figure B-9

(1) Countermobility. Non-engineer maneuver units (except for artillery) cannot perform countermobility tasks with organic capability. The two classes of tasks, minefields and linear obstacles, are modeled strictly as engineer unit capabilities. Pre-planned minefield locations must be scripted in the input data. Other minefields may be dynamically emplaced by artillery or emplaced by engineers through decision tables. Minefield emplacement tasks are activated as a function of the location of the maneuver unit and supporting engineer unit, and the minefield site. Linear obstacle emplacement

CURRENT REPRESENTATION OF ENGINEER TASKS IN VIC

	Task Effects Modeled?	Capability of Non-engineer Unit? ¹	Capability of Engineer Unit? ¹
Countertermobility:			
Minefields	Yes	No ²	Yes ³
Linear obstacles	Yes	No	Yes ³
Point obstacles	No	No	No
Complex obstacles	No	No	No
Mobility:			
Minefield breaches	Yes ⁴	Implied	Implied ⁵
Linear obstacle breaches	Yes ⁴	Implied	Implied ⁵
Complex obstacle breaches	No	No	No
Point obstacle breaches	No	No	No
Improve assault breaches	No	No	No
Assault river crossings	Yes	Implied	Yes
River crossing sites	No	No	No
Pioneer trails	No	No	No
Airlanding facilities	No	No	No
Survivability:			
Direct fire positions	Yes ⁶	Explicit	Yes
Indirect fire positions	No	No	No
Sustainment Engineering:			
Main supply routes	No	No	No
CS and CSS sites	No	No	No

¹Engineer equipment is implicitly modeled.

²Artillery can emplace a minefield using FASCAM munitions.

³The execution of this task can be scripted or generated dynamically.
The site for obstacle emplacement must be scripted in model input data.

⁴Delay and/or attrition are functions of the obstacle and do not depend on capabilities of breaching/crossing units.

⁵Capability is identical to that of non-engineer units. Engineer units cannot be tasked to perform this mission.

⁶Subsequent repair and improvement tasks are not modeled.

Figure B-10

options in VIC are very similar to the minefield options. VIC does not explicitly play point obstacles.

(2) Mobility. VIC models the delay and attrition that is associated with several mobility functions. However, in general, it does not model obstacle breach activity as an engineer unit capability. Instead, breaching is performed by the maneuver unit encountering the obstacle -- with resources that are implicitly assumed as available. The only exception is that engineer assistance is requested when a unit encounters a linear obstacle which must be crossed using a bridge. In this case, however, input data can still specify a capability to cross the gap even if engineer unit help is not immediately available. Subsequent improvements to a breach of any linear obstacle type (e.g., fixed bridging) are not presently modeled.

(3) Survivability. The only survivability task modeled in VIC is preparation of fighting positions. These positions currently must be scripted in the input data. Thus, it is not currently possible to call for preparation of positions at a path point that is dynamically generated by a VIC decision table. VIC can provide an explicit capability for all modeled units (including engineer survivability teams) to perform this task.

b. **Desired improvements.** The areas in VIC where improvement is desired can be derived by comparing the desired level of engineer play, as listed in Figure B-9, and the current level of engineer play, as depicted in Figure B-10. Figure B-11 lists these desired improvements. The focus of these improvements is primarily to introduce additional tasks that engineers commonly perform in the corps' area of operation. In conjunction with the addition of these engineer tasks, the tactical effects resulting from the execution of these tasks certainly must be incorporated in VIC. These improvements are further described in the remainder of this paragraph.

(1) General.

(a) The model should permit requests for engineer unit assistance for each type of task that engineers are expected to accomplish in the corps area. Engineers should execute those tasks consistent with available capability and resources.

(b) All engineer units in VIC should have the capacity to perform each type of engineer task in the scenario. This will remove the artificial constraint that engineer units at only the lowest level are capable

DESIRED IMPROVEMENTS TO VIC ENGINEER REPRESENTATION

Task	Code	Improvement
General:		
	G1	Revise the engineer unit representation and the method of resource allocation. Ensure that combat engineers and equipment are subject to the effects of attrition and that attrition affects engineer task performance capability
	G2	Ensure that engineer task performance of non-engineer units is commensurate with ability
	G3	Account for effects of night, weather, smoke, and NBC on engineer task performance
	G4	Add postprocessor reports that capture performance (and non-performance) of all engineer tasks
	G5	Fully integrate combat engineers and their equipment and materiel with the Logistics Module and Return-to-Duty Module
	G6	Revise VIC's coordinated group move logic so that maneuver units will encounter terrain effects (including minefields and other obstacles) during such moves
	G7	Add capability for maneuver units to use roads
	G8	Add capability to degrade and damage roads and MSRs
Counter mobility:		
Minefields	CM1	Add capability for helicopter/aircraft-delivered scatterable mines
	CM2	Add capability to close lanes in minefields
Linear obstacles	CM3	Add capability for dynamic site selections and emplacements
	CM4	Add capability to close lanes in linear obstacles
Complex obstacles	CM5	Add dynamic capability for engineer units to emplace complex obstacles
Point obstacles	CM6	Add capability for scripted and dynamic point obstacle emplacements
	CM7	Allow synergistic effects of point obstacles

Figure B-11 (Continued on Next Page)

DESIRED IMPROVEMENTS TO VIC ENGINEER REPRESENTATION -- Continued

Task	Code	Improvement
Mobility:		
Minefield breaches	M1	Add dynamic capability for engineer units to breach minefields
	M2	Add capability to request breaches by engineer units, to include requests from units bypassing minefields
	M3	Add more parameters for selecting the appropriate breaching tactic (bypass, bull, breach)
	M4	Add capability for subsequent improvement of minefield breaches by engineer units
Linear obstacle breaches	M5	Add dynamic request and capability for engineer units to breach linear obstacles
	M6	Add capability to search for nearby paths across obstacles before breaching
	M7	Add capability to create multiple breaches on a single linear obstacle segment
	M8	Add capability for subsequent improvements of linear obstacle breaches by engineer units
Complex obstacle breaches	M9	Add dynamic capability for engineer units to breach complex obstacles
Point obstacle breaches	M10	Add capability for engineer units to breach point obstacles
	M11	Add capability for non-engineer units to breach with organic resources or request engineer unit support
Assault river crossings	M12	Add capability to cross gaps by means other than bridging (fording, bypass, breaching)
	M13	Ensure that gaps which require bridging cannot be breached without bridging
	M14	Ensure that bridge asset availability is modeled explicitly
River crossing sites	M15	Add capability for subsequent improvement of river crossing sites by engineer units with fixed bridging

Figure B-11 (Continued on Next Page)

DESIRED IMPROVEMENTS TO VIC ENGINEER REPRESENTATION -- Continued

Task	Code	Improvement
Mobility (continued):		
Pioneer trails	M16	Add capability for engineer units to prepare and maintain pioneer trails (scripted and dynamic)
Airlanding facilities	M17	Add capability for engineer units to prepare and maintain forward airlanding facilities (scripted and dynamic)
Survivability:		
Direct fire positions	SV1	Add dynamic capability for engineer units to prepare fighting positions
	SV2	Add dynamic capability for engineer units to perform subsequent repairs and improvements to fighting positions
Indirect fire positions	SV3	Add capability for engineer units to prepare and maintain protective positions for indirect fire and other systems (scripted and dynamic)
Sustainment engineering:		
Main supply routes	ST1	Add capability for engineer units to maintain and repair roads and MSRs (scripted and dynamic)
CS and CSS sites	ST2	Add capability for engineer units to prepare and maintain sites (scripted and dynamic)

Figure B-11

of performing one of four specific tasks. Also, non-engineer maneuver units should accomplish engineer-related tasks that are commensurate with their abilities to perform them.

(c) The tactical effects that result if an engineer task is (or is not) performed must be modeled. The tactical effects on engineer units performing tasks must also be modeled.

(d) Unit composition and equipment, as it affects task performance capability, should be identified. Vulnerability of unit assets

should be identified and attrition must be assessed. The attrition must, in turn, affect task performance capability.

(e) It is important that the model limit the commitment of engineer units to realistic performance levels -- to include degrading performance due to night, weather, smoke, and NBC effects. Engineer units must be constrained to the capability of the force structure in the scenario modeled.

(f) All maneuver unit movements should encounter the effects of terrain, minefields, and other linear obstacles. Maneuver units should be capable of using roads. Roads and MSRs should be subject to degradation through use or attack.

(2) Countermobility.

(a) VIC should permit rapid reseeding of minefield lanes during retrograde operations.

(b) VIC should allow dynamic site selection and emplacement of minefields and linear obstacles. VIC should also permit rapid closing of lanes in minefields and other linear obstacles during retrograde.

(c) VIC does not allow maneuver units to take advantage of roads, degradation of the road network, and modeling of point obstacles. When surrounding terrain does not permit an easy bypass, point obstacles can have a significant role in battle results. The capability to model point obstacles should be added to VIC if maneuver units are allowed to take advantage of roads or pioneer trails. Further, VIC should allow a synergistic effect to be associated with point obstacles and direct/indirect fires.

(d) It should be possible to dynamically request all countermobility engineer tasks depending on battle conditions. Whether the request is made for engineer support to perform the task, or whether it is performed with resources available to the maneuver unit, depends on the existence of those resources. In addition to the dynamic creation of these requirements, VIC should also dynamically create sites for these tasks.

(3) Mobility.

(a) Except for tactical bridging operations, VIC does not model engineer unit performance of mobility tasks. VIC should model requests for engineer unit assistance from maneuver and other units encountering minefields and obstacles.

(b) VIC should more realistically model a commander's selection of which tactic to employ (breach, bull, or bypass) when encountering a minefield.

(c) VIC should model the possibility that multiple breaches of a linear obstacle may be prepared, each one resulting in further reduction of obstacle crossing times.

(d) Available intelligence should include data on linear obstacle breaches in accordance with rules set forth by intelligence experts. VIC should permit a maneuver unit encountering a point or linear obstacle to consult available intelligence to determine if a breach has already been made at a distance that would permit the unit to dynamically change its path to take advantage of the breach.

(e) VIC does not model the breach of a point obstacle; this capability should be added.

(f) VIC should model the improvement of a wet or dry gap crossing site with an engineer task to install fixed bridging. User input should control the rate and total time of engineer resource expenditure. Bridging materiel should be modeled in VIC as distinct entities with limited quantities. Task performance should result in reduced obstacle crossing rates.

(g) VIC should model bridge retrieval tasks.

(h) VIC should model the preparation and maintenance of pioneer trails. Task performance should result in increased grid square trafficability.

(i) VIC should model the engineer tasks associated with forward airlanding facilities such as preparing and maintaining helicopter landing zones, forward arming and refueling points, low-altitude parachute extraction sites, and landing strips.

(4) Survivability.

(a) VIC does not model degradation of direct fire positions. If this capability is added, VIC should be altered to permit subsequent repair and improvement tasks associated with these positions. These tasks should be generated if the unit expects to continue to occupy the position for a time exceeding a user-defined minimum (improvement) or if there has been more than a user-defined minimum degradation (repair).

(b) VIC does not model tasks to prepare positions for indirect fire and other systems.

(5) Sustainment engineering.

(a) VIC does not model MSR degradation and interdiction. This should be added. After this is done, VIC should be further improved by adding the effects of engineer tasks to repair and maintain the MSRs.

(b) VIC does not model a corps' rear-area activities except for supply operations and return-to-duty for soldiers and equipment. If the modeling of this area of the corps is strengthened in VIC, then the effects of engineer tasks to prepare and maintain various CS and CSS sites should be added.

19. Conclusions.

a. The VIC model currently represents some engineer tasks and the effects of those tasks well. However, many tasks and effects are represented poorly or not at all. Therefore, the representation of engineers, the execution of engineer tasks, and the results from the execution (or non-execution) of those tasks need improvement in VIC.

b. To maintain a reasonable and balanced representation in VIC, engineer units should continue to be modeled with explicit maneuver and task-execution capability. However, the representation of engineer unit capability under a more flexible arrangement could improve the realism of the current tasks played in the model and permit adding additional engineer tasks that are commonly performed in a corps' area of operations.

c. The analytic community is currently using VIC in capability-constrained studies, not requirements-unconstrained studies. The use of VIC in this manner is not expected to change in the near future. Unless VIC is exported to users outside of TRAC, the engineers should continue to be modeled under a constrained environment. The engineer capability to perform tasks in VIC should be limited to that expected of the engineer force as defined in the VIC scenario.

V. ANALYSIS OF ENHANCEMENTS AND RECOMMENDATIONS

20. General. This section describes results of the analysis of the 37 desired improvements listed in Figure B-11. The analysis was performed in order to develop a logical, prioritized program and schedule to improve the engineer representation in the VIC model.

21. Assessment Results.

a. Evaluation criteria. Due to the complexity and somewhat subjective nature of this analysis, ESC used several criteria for this evaluation. The criteria were:

- The likely impact of the improvement on model results
- Impact of improvements on VIC run time and software maintenance
- The likely impact of the improvement for engineer-specific analysis
- Time required to program the improvement
- Difficulty in providing required data and tactical decision rules (doctrine)
- The logical (predecessor/successor) relationship of the improvement with other improvements
- Possible reduction in programming time by grouping the improvement with others
- Coordination required (data gathering or specification development) outside of the engineer community
- Degree of expected acceptability by VIC users or the VIC proponent (TRAC-WSMR)

Together, these criteria were used to assess which improvements should be adopted for inclusion in VIC and the order in which they should be addressed. ESC did not assign weighting factors to the criteria. The following paragraphs summarize the results of this assessment in relationship to these criteria.

b. Impact on model results. The tasks from Figure B-11 with the greatest potential impact on model results are tasks G1 (revising engineer

unit representation), G7 (allowing maneuver units to use the road network), G8 (degrading and damaging roads), CM3 (selecting and emplacing linear obstacles dynamically), M1 (dynamic minefield breaching by engineer units), M5 (dynamic linear obstacle breaching by engineer units), and M13 (ensuring that gaps that require bridges are breached only by using bridges). Task G6 (revising the coordinated group move) and CM1 (adding capability for air-delivered scatterable mines) are also rated as having a significant potential impact on model results. These tasks were scheduled for early implementation, unless other evaluation criteria (for example, logical sequencing or task grouping) suggested delayed implementation.

c. **Engineer-specific analysis.** Even though it has no impact on model results, one task (task G4, adding postprocessor reports for engineer tasks) is included as an improvement to VIC because it is important for engineer-specific analysis. As the Army's mid-resolution, corps-level model, ESC believes that an Engineer Functional Area Model (EFAM) is needed to provide a more detailed analysis related to engineer-specific functions. This analysis model would be used by an agency outside of TRAC (that is, the US Army Engineer School). Therefore, ESC anticipates that the results of VIC runs will be used for analysis by an EFAM. These results would be captured within VIC postprocessor reports and would provide valuable data relating to the engineer tasks performed in VIC model runs.

d. **Impact on model run time.** Since the engineer module consumes only a small part of VIC's total run time, ESC believes that the improvements added to the engineer module will have a only minor impact to the overall run time. It is possible that improvements to the efficiency (execution speed) of existing and new computer code could actually provide a net decrease to the model's run time, even with the new improvements incorporated. The new computer program code could be written with liberal use of in-line comments, meaningful variable names, and without abstract algorithms. Such code should not cause significant new problems for the model proponent, software maintenance personnel, and model users.

e. **Level of effort.** With the exception of task G7 (allowing maneuver units to take advantage of the road network), ESC believes that no individual task should require more than six months of programming effort. Most should require much less. Several could be completed in about a week.

The greater problem is the availability of valid data and tactical decision rules to implement the new computer code. This evaluation did not examine the data sets being used by VIC. Resource estimates for obtaining data sets for the proposed improvements are estimated.

f. **Sequencing.** Logical sequencing of tasks had a major influence on the order of selection of tasks for implementation. There were two primary examples of this effect.

(1) Because the representation of point obstacles would have only marginal value unless maneuver units were allowed to use the roads, ESC postponed this improvement until the use of roads was fully implemented in VIC. Several other tasks were also dependent on this capability being established first.

(2) Rapidly and efficiently adding realistic representation of new engineer tasks in VIC is dependent on a revised representation of engineer units. The current representation in VIC is believed to be too inflexible to permit easy addition of new engineer unit capabilities and model the effects of personnel and equipment attrition on task performance capability. Thus, ESC placed the task to improve engineer unit representation first.

g. **Task groupings.** Grouping certain sets of tasks for implementation as a "block" could reduce the total amount of time required as compared to programming each task individually. Such cases were considered carefully to determine if the time saved was worthy of raising its priority for implementation.

h. **Coordination.** Four tasks in particular will require coordination outside of the engineer community. The objectives of the coordination are both to achieve a consensus for the specification of new program code and to assemble a reasonable data set to drive the new code. The four tasks are G6 (revise the coordinated group move), CM1 (add aircraft and helicopter-delivered minefields), M17 (add forward airlanding facility engineer tasks), and G7 (allowing use of the road network by maneuver units). Since most of the code to be revised or added is in VIC modules which are primarily outside of the influence of engineer interactions in VIC, it is preferable that the model proponent (TRAC-WSMR) take the lead in initiating these improvements. This arrangement would also have the advantage of encouraging and enhancing the acceptance of these changes by other model users.

22. Recommendations. This analysis resulted in the regrouping of the 37 improvement tasks identified in Figure B-11. Figure B-11 grouped improvements according to engineer functions. The new grouping places these tasks in four categories for a phased implementation.

a. **Phase One.** Figure B-12 displays the improvement tasks that should be accomplished first. Although fourteen improvements are listed in this phase and should begin in Phase One, only four of the improvements in the "general" category (G1, engineer unit representation; G2, ensuring that engineer capability of non-engineer units is commensurate with ability; G3, degradations to engineer task performance; and G5, adding engineer materiel resource constraints) are expected to be completed by the end of this phase. Six improvement tasks will not be complete until Phase Two. Programming of these six tasks can begin without the provision of data, but they cannot be completed until the required input data is provided. The four remaining tasks (G6, revise coordinated group move; G7, allowing maneuver units to use roads; CM1, air-delivered mines; and M17, forward airlanding facilities tasks) may extend into a later phase. Coordination of these four improvements should begin in Phase One, but the length of time for this coordination with the model proponent and users cannot be determined.

(1) Although they could have a significant impact in VIC, task G8 (degrading and damaging roads) and task M13 (ensuring that gaps that require bridges are breached only by using bridges) are not included in Phase One. Instead, they are placed in Phase Two to allow for logical sequencing and grouping of these improvements with others.

(2) The major improvement tasks in Phase One are the revision of VIC's representation of engineer units -- their resource allocation, attrition, degradations to performance, and supplies. This work must come first to provide the logical framework for incorporating additional engineer task improvements. The remaining Phase One tasks consist of establishing the basis for incorporating engineer improvements in the Engineer Module and Terrain and Barriers Module.

(3) The proposed engineer unit representation will provide a more flexible and realistic representation of engineer capabilities in VIC.

VIC ENGINEER REPRESENTATION -- PHASE ONE IMPROVEMENTS

Task	Code	Improvement
General:		
	G1	Revise engineer unit representation and method of resource allocation. Ensure that engineer attrition is modeled
	G2	Ensure that engineer task performance of non-engineer units is commensurate with ability
	G3	Account for effects of night, weather, smoke, and NBC on engineer task performance
	G5	Fully integrate combat engineers and their equipment and materiel with the Logistics Module and Return-to-Duty Module
	G6*	Revise VIC's coordinated group move logic so that maneuver units encounter terrain effects
	G7*	Add capability for maneuver units to use roads
Counter mobility:		
Minefields	CM1*	Add capability for helicopter/aircraft-delivered scatterable mines
Linear obstacles	CM3**	Add capability for dynamic site selections and emplacements
Mobility:		
Minefield breaches	M1**	Add dynamic capability for engineer units to breach minefields
	M2**	Add capability to request breach, including requests from units bypassing minefields
	M4**	Add capability for subsequent improvement of minefield breaches by engineer units
Linear obstacle breaches	M5**	Add dynamic request and capability for engineer units to breach linear obstacles
Airlanding facilities	M17*	Add capability for engineer units to prepare and maintain forward airlanding facilities (dynamic and scripted)
Survivability:		
Direct fire positions	SV1**	Add dynamic capability for engineer units to prepare fighting positions
Indirect fire positions	SV3**	Add capability for engineer units to prepare protective positions for indirect fire and other systems (scripted and dynamic)

*Coordination for adding this improvement to VIC begins in this phase. If approved, the task will be completed in a later phase.

**Task completion will extend into Phase Two.

Figure B-12

Rather than using teams with fixed capability, engineer units will be task-organized as needed to perform specific missions. All engineer assets will belong to a "superior" engineer unit and will be assigned to work units as needed to accomplish specific missions. This form of representation will improve the current engineer representation in the following ways:

- Allows for variable resolution of resource representation
- Provides a mechanism for improved, dynamic engineer force structure representation
- Models multi-mission capability of engineer resources

(4) ESC estimates that computer programming efforts require about six calendar months and one professional staff year of effort to support Phase One. Only minimal guidance on concepts and doctrine will be needed in this phase. About one professional staff month is needed to gather the data for this first phase. Both parts of the overall effort can begin simultaneously.

b. **Phase Two.** Figure B-13 lists the tasks for Phase Two. Every task in this figure should be completed at the end of Phase Two. Any task involving dynamic capabilities must have tactical decision rules identified to determine which conditions encountered during model play will call for the new capability to be exercised. The concepts and doctrine for these decision rules must be provided *before* computer programming can begin.

(1) The Phase Two work will enhance VIC engineer representation in two areas. First, the foundation that began in Phase One for incorporating a host of engineer tasks will provide a more complete set of engineer task effects for gaming in VIC. Second, task G4 (adding engineer postprocessor reports) will be implemented to extract engineer-related task data from VIC.

(2) Phase Two work involves about one professional staff year of programming effort over a six-month time period. Data gathering and generation of tactical decision criteria from doctrine could be difficult and could require as much as two professional staff months. The tactical decision data must be provided before computer programming can begin, so this effort should start well in advance of the start date of the programming effort.

VIC ENGINEER REPRESENTATION -- PHASE TWO IMPROVEMENTS

Task	Code	Improvement
General:		
	G4	Add postprocessor reports that capture performance (and non-performance) of all engineer tasks
	G8	Add capability to degrade and damage roads and MSRs
Countermobility:		
Linear obstacles	CM3*	Add capability for dynamic site selections and emplacements
Mobility:		
Minefield breaches	M1*	Add dynamic capability for engineer units to breach minefields
	M2*	Add capability to request breach, including requests from units bypassing minefields
	M4*	Add capability for subsequent improvement of minefield breaches by engineer units
Linear obstacle breaches	M5*	Add dynamic request and capability for engineer units to breach linear obstacles
	M8	Add capability for subsequent improvements of linear obstacle breaches by engineer units.
Assault river crossings	M13	Ensure that gaps which require bridging cannot be breached without bridging
	M14	Explicitly model bridge asset availability linear obstacle breaches by engineer units
Survivability:		
Direct fire positions	SV1*	Add dynamic capability for engineer units to prepare fighting positions
Indirect fire positions	SV3*	Add capability for engineer units to prepare protective positions for indirect fire and other systems (scripted and dynamic)

*Task began in Phase One and will be completed in this phase.

Figure B-13

c. **Phase Three.** Figure B-14 displays the tasks that are scheduled for completion in the third phase of VIC improvement effort. In general, these tasks are associated with lower-priority engineer tasks (in terms of impact on model outcome) and/or require additional programming time than the tasks addressed in phases one and two. Phase Three effort is expected to require about six calendar months and one professional staff year of programming effort. Only a minimal effort will be necessary to provide guidance on concepts and doctrine for the programming work. The data provision requirement for this task is estimated at roughly one-half professional staff month.

VIC ENGINEER REPRESENTATION -- PHASE THREE IMPROVEMENTS

Task	Code	Improvement
Countermobility:		
Complex obstacles	CM5	Add dynamic capability for engineer units to emplace complex obstacles
Mobility:		
Complex obstacle breaches	M9	Add dynamic capability for engineer units to breach complex obstacles
River crossing sites	M15	Add capability for subsequent improvement of river crossing sites by engineers with fixed bridging
Sustainment engineering:		
Main supply routes	ST1	Add capability for engineer units to maintain and repair roads and MSRs (scripted and dynamic)
CS and CSS sites	ST2	Add capability for engineer units to prepare and maintain sites (scripted and dynamic)

Figure B-14

d. **Other improvements.** Figure B-15 lists tasks which fall into two categories: (1) those improvements that are dependent on coordination outside of the engineer community; and (2) those improvements that represent desirable, but not required, additions to VIC. Coordination of the four tasks

VIC ENGINEER REPRESENTATION -- OTHER IMPROVEMENTS

Task	Code	Improvement
General:		
	G6*	Revise VIC's coordinated group move logic so that maneuver units encounter terrain effects
	G7*	Add capability for maneuver units to use roads
Counter mobility:		
Minefields	CM1*	Add capability for helicopter/aircraft-delivered scatterable mines
Point obstacles	CM6**	Add capability for scripted and dynamic point obstacle emplacements
	CM7**	Allow synergistic effects of point obstacles
Mobility:		
Minefield breaches	M3	Add more parameters for selecting the appropriate minefield breaching tactic (bypass, bull, breach)
Linear obstacle breaches	M6	Add capability to search for nearby paths across obstacles before breaching
	M7	Add capability to create multiple breaches on a single linear obstacle segment
Point obstacle	M10**	Add capability for engineer units to breach point obstacles
	M11**	Add capability for non-engineer units to breach point obstacles or request engineer unit support
Assault river crossings	M12	Add capability to cross gaps by means other than bridging (fording, bypass, breaching)
Pioneer trails	M16**	Add capability for engineer units to prepare and maintain pioneer trails (scripted and dynamic)
Airlanding facilities	M17*	Add capability for engineer units to prepare and maintain forward airlanding facilities (scripted and dynamic)

* Coordination for adding this task began in Phase One.

** Task is contingent on the completion of task G7.

Figure B-15

which fall in the first category began in Phase One because of the anticipated lead time and interaction that must take place with the model proponent and users. They must understand that the primary benefit of these revisions in the model is to provide more realism in VIC results. They must also accept that scenario development will not become more difficult and model run time will not be adversely affected. Because of the uncertainty surrounding these tasks, manpower and time estimates necessary to accomplish these improvements, even given an existing specification, cannot be made at this time.

(1) Task G6 (modify coordinated group move code to ensure that all maneuver units are subject to terrain effects) will likely have a significant impact on the results of model play. This improvement is necessary to ensure that terrain effects are adequately represented. The engineers should, through the VMUG, take the lead in this revision to VIC.

(2) Task G7 (adding capability for maneuver units to use roads), as previously discussed, is a very difficult task to implement. Proponency for developing the task specification cannot logically be assigned to a single organization due to magnitude of its impact on many functional areas. The engineers should also take the lead in attaining this capability in VIC. If task G7 is eventually implemented in VIC, then work could begin on tasks that relate to roads and point obstacles (CM6, CM7, M10, M11, and M16).

(3) The majority of the new computer program code which must be developed in response to task CM1 (helicopter/aircraft-delivered minefields) will be in VIC modules that are not currently influenced by engineer-related modules. Again, outside coordination may be necessary. Due to insufficient experience in the engineer community of the characteristics of the existing code that would have to be modified, ESC is unable to specify the programming changes necessary to implement this task. Therefore, manpower and time requirements cannot be estimated.

(4) Task M17 (forward airlanding facilities) has several factors not supporting its early incorporation in the VIC improvement program. The impact of implementing this task in VIC is not known due to the engineer community's unfamiliarity with the Global Air Module and the other related modules. It is anticipated that data provision would be very difficult and that several other modules would be impacted. Further, it would be difficult to validate the accuracy of data supporting the new code.

(5) The remaining tasks in Figure B-15 are additions to VIC that ESC considers to be less important to the overall representation of engineer effects.

(a) Task M3 (adding additional selection criteria for minefield breaches), if implemented, would provide an improvement to a capability that VIC models fairly well already. The effort to develop tactical decision rules to govern choice of minefield breaching tactic would be difficult, and in most cases would yield results in agreement with what VIC currently provides. Therefore, this task should be delayed to near the end of the effort to upgrade VIC's engineer representation due to the perceived difficulty of implementing the task (from a data standpoint) and the marginal incremental improvement that would ensue.

(b) Task M7 (creating multiple breaches on a single linear obstacle line segment) could be handled by alternative methods, such as simply using smaller line segments.

(c) Task M12 (crossing gaps by means other than bridging) would be difficult to implement (also from the standpoint of data availability) and would provide a relatively minor impact on model outcomes. Terrain data, in general, is not available in sufficient resolution to drive the tactical decision rules that would be required to govern the selection of a specific breaching technique.

e. **Omitted tasks.** Three tasks from Figure B-11 were omitted as a result of this analysis of improvements. The relative impact of task SV2 (dynamically repair and improve direct fire positions) on model results, compared with the difficulty of implementing it in the model, is not significant enough to warrant the expenditure of effort. Not only would the repair task have to be modeled, but the code to generate the weathering and damage (and their effects on vulnerability) would also have to be developed. Lastly, tactical decision rules to specify the conditions under which repair would be requested would also have to be generated. Also, the engineer improvement tasks for adding capability to close lanes in minefields (CM2) and other linear obstacles (CM4) were judged to have only marginal value. VIC's current terrain resolution is not sufficiently detailed to model this task.

f. Other recommendations.

(1) With the improvements described above, ESC believes that VIC will yield results that would be generally consistent with a more-detailed representation of engineer capability in a model such as that proposed in an EFAM. (See Annex D, "Engineer Functional Area Model.")

(2) The first three phases of improvements as described in Figures B-12, B-13, and B-14 should be resourced and sequentially implemented. It is important to note that before programming can begin, the tactical decision rules for executing engineer tasks must be specified. Data sets to support these improvements could be developed, for the most part, in parallel with model programming.

(3) TRAC-WSMR is the model proponent and would be the most likely organization to make these recommended programming changes. However, TRAC-WSMR has recently lost its two most senior VIC programmers, and it continues to aggressively accomplish a heavy study workload using VIC. Therefore, ESC recommends that CERL be designated as the programming activity, tasked, and funded to make these improvements because of CERL's prior experience in working with VIC.

(4) CERL would have the responsibility to work with TRAC-WSMR to validate the software developed and demonstrate the effects of the software on the model as a whole. CERL would also have the responsibility for documenting the software for both users and programmers.

(5) The US Army Engineer School (USAES) should have the responsibility for providing the concepts and doctrine to support the programming of the tactical decision rules. The USAES should also have the lead responsibility (in conjunction with the US Army Materiel Systems Analysis Activity) for providing the data sets to support the model.*

(6) As the facilitator of engineer model initiatives, ESC will continue to monitor and coordinate with the engineer and modeling community to ensure that the VIC engineer model improvement program remains on track. ESC's role includes monitoring and coordinating the development of data sets and tactical decision rules for some of the improvements that primarily affect

*Due to the impending move of the USAES to Fort Leonard Wood, the USAES may be unable to support this effort on a timely basis.

the engineers and ensuring that the model proponent and users agree in principle to the improvements in engineer representation in VIC.

g. **Interim Measures.** Until the improvements described above are implemented in VIC, the scenario developers and other model users should immediately strive to implement the thrust of these recommendations through input data. For example:

- Represent linear obstacles as short segments so that breaching a single segment will not create an artificially large gap in the obstacle.
- Use pseudo-infinite breach times for major river crossings for maneuver units without bridge assets. This will prevent units from performing a breach that is physically impossible.
- Use coordinated move groups as sparingly as possible consistent with maintaining reasonable model run times. Units in a coordinated group move status do not encounter terrain features, including minefields and other obstacles. This is unrealistic and masks the value of engineer support.

ANNEX C
FORCEM EVALUATION

ANNEX C
FORCEM EVALUATION

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I. INTRODUCTION

1. Purpose. This annex examines engineer play in the Force Evaluation Model (FORCEM), discusses different methods to improve its engineer representation, and finally presents a strategy for achieving the desired improvements.

2. Scope. This review of FORCEM is deliberately focused on engineer play and parallels the assessment of engineer representation in other major Army models being made by the US Army Engineer Studies Center (ESC). Other functional areas and model elements were examined only to the extent that they influence, or should influence the use of engineer forces. Particular aspects of the model that hamper or frustrate the representation of engineer play are identified and in some cases included as part of the proposed changes.

3. Background. FORCEM is an automated, two-sided, time-stepped, deterministic, and symmetric theater-level war game. It plays both ground and air combat. Unlike most other theater models, it has a multi-tiered decision-making framework, represents combat service support (CSS) forces at echelons above corps (EAC), and has the ability to show the impact on combat of support capabilities and shortfalls. The following paragraphs give some perspective to what FORCEM is.

a. Theater-level models. The complexities of modern warfare (the costs, the types of forces, the theater, the weapons, etc.) make it impossible to plan for and allocate the resources necessary to ensure the defense of the United States (US) and the protection of its national interests without extensive data and computational support. High-resolution models, simulating weapon or small unit engagements can use detailed (often mathematical) representations of performance characteristics, line-of-sight, communications, etc. Models that examine warfare on a large scale, i.e., theater or global simulations such as TACWAR¹ or CEM², must generalize components and effects. These lower-resolution models are physically unable to include every conceivable contributing component in a model, and are unable to predict the vagaries of large force on force actions. More importantly, they cannot duplicate the human element in strategic decisionmaking. These shortcomings are frequently

¹Kerlin, Edward, *IDA TACNUC Model: Theater-Level Assessment of Conventional and Nuclear Combat* (Institute for Defense Analysis, October 1975).

²Concepts Evaluation Model (CEM) (US Army Concepts Analysis Agency [CAA]).

criticized by both the government (a General Accounting Office [GAO] report³ confirmed the need, but challenged model and results verification procedures) and private reviewers (see Allen⁴ for a current, albeit alarmist view of how war games have evolved and have been used in making decisions). Despite these criticisms, theater models are accepted tools for planners and have become indispensable adjuncts to the decisionmaking process.

b. **History of FORCEM.** In July of 1981 an Army Regulation (AR) ordained a hierarchy of war games at the theater, corps/division, combined arms, and support task force levels.⁵ These models would be developed and implemented to facilitate the evaluation of combat capabilities and determine resource requirements. The impetus for the program came from the "Hardison Report," an examination sponsored by the Deputy Undersecretary of the Army (Operations Research) of Army study organizations and products.⁶ The report found a proliferation of models, systems, and games (MSGs) that could neither be linked together nor used with common data bases. The regulation further tasked CAA with developing the theater model. CAA initially planned to modify its CEM model to achieve the goals of FORCEM. In the Spring of 1982, however, CAA rejected this concept in favor of an entirely new design effort. Development proceeded through the period 1982 to 1985 when the first working version was completed. Important to the purpose of this annex was the work performed by the US Army Construction Engineering Research Laboratory (CERL). It collaborated with CAA in designing an engineer submodel for FORCEM.

c. **Model usage.** FORCEM has been used on three major CAA studies: *US Army Operational Readiness Analysis-1985 (OMNI²US-85)*, *OMNIBUS-86*, and the *Combat-Support Ratio Study*. FORCEM was used in the first study for demonstration purposes, while the latter two efforts were full-fledged study

³*Models, Data, And War: A Critique of the Foundation For Defense Analyses* (Comptroller General of the United States, 12 March 1980).

⁴Allen, Thomas B., *War Games* (McGraw Hill, 1987).

⁵*Army Model Improvement Program (AMIP)*, AR 5-11 (July 1981).

⁶*Review of Army Analysis* (Department of the Army [DA] Special Study Group, April 1979).

applications. The model is expected to become CAA's, and therefore, the Army's primary theater-level model.

d. **Configuration management.** CAA is currently the exclusive owner and operator of the model. While other Army war game designing organizations have instituted standardization groups to control the proliferation of unregulated or undocumented model versions, no other Army agency or element has a mission which overlaps the theater-level analyses that CAA conducts. The overhead in running a FORCEM-sized model will probably discourage other agencies from acquiring it, if the experience with the CEM is any indication. Thus, changes to the model, whether internally or externally generated, would likely be implemented and controlled by CAA.

4. **Method.** The approach ESC used for this assessment proceeded as follows:

a. First, the FORCEM model was studied to identify its major functional areas and review the engineer representation (structure and procedures). Those model elements that would directly or indirectly influence engineer play were also examined.

b. Second, ESC reviewed the engineer missions that are applicable to the FORCEM environment, especially engineer missions at EAC.

c. Third, was the key phase in which real world engineer missions were compared to FORCEM's present representation. This comparison considered adequacy of representation, effect on the model, and difficulty and extent of modifications, if necessary.

d. Finally, a list of recommended actions was prepared to be used in developing the overall plan to improve engineer modeling in the Army.

II. DESCRIPTION OF THE MODEL

5. Sources. Although FORCEM has been used as the analytical basis for several major CAA studies, the model continues to evolve. As with most computer systems, changes to documentation lag behind code and logic revisions. Consequently, there is no published document that reflects the current state of the model and all its components. Separate documents of varying currency and accuracy exist for Fire Support, Command and Control (C²), Movement, CSS, Data Input, and Model Output. ESC had to supplement existing documentation with a review of FORCEM's code and discussions with CAA personnel. ESC also used various documents prepared by CERL describing existing and proposed engineer module structures and logic.^{7,8}

6. Operational Environment.

a. Hardware and Systems Software. As with any computer model, the structure of FORCEM is very much a product of the computer hardware and software environment in which it is implemented. It is implemented on a UNISYS 1100/84 computer having 4 mega-words (36 bits) of main memory, and uses the EXEC operating system. The model is written in SIMSCRIPT II.5, which, not coincidentally, is the language in which the other Army models in the hierarchy are written.⁹ Several early portions of the model were written in FORTRAN, but they were later converted to SIMSCRIPT for consistency.

b. Software. Here we will distinguish systems software (compilers and operating system) from the user-created software that would be used in a FORCEM application. Figure C-1 shows the major programs that would be used in any study using FORCEM. Note that the entries within the boxes are programs: TRANSMO is a strategic mobility model; ATCAL extrapolates division results from combat samples (force composition and combat attrition data); and COSAGE is a model developed at CAA initially for the analysis of wartime ammunition,

⁷Evans, John W., *Conceptual Design of the Engineer Module for the Theater-Level Force Evaluation Model (FORCEM)*, Technical Report P-87/15 (USA-CERL, September 1987).

⁸"Engineer Representation in the Force Evaluation Model (FORCEM)," letter from CERL to ESC, 24 December 1987.

⁹Kiviat, et. al.; edited by E. C. Russell, *SIMSCRIPT II.5 Programming Language* (CACI, Inc., 1975).

FORCEM's SOFTWARE ENVIRONMENT

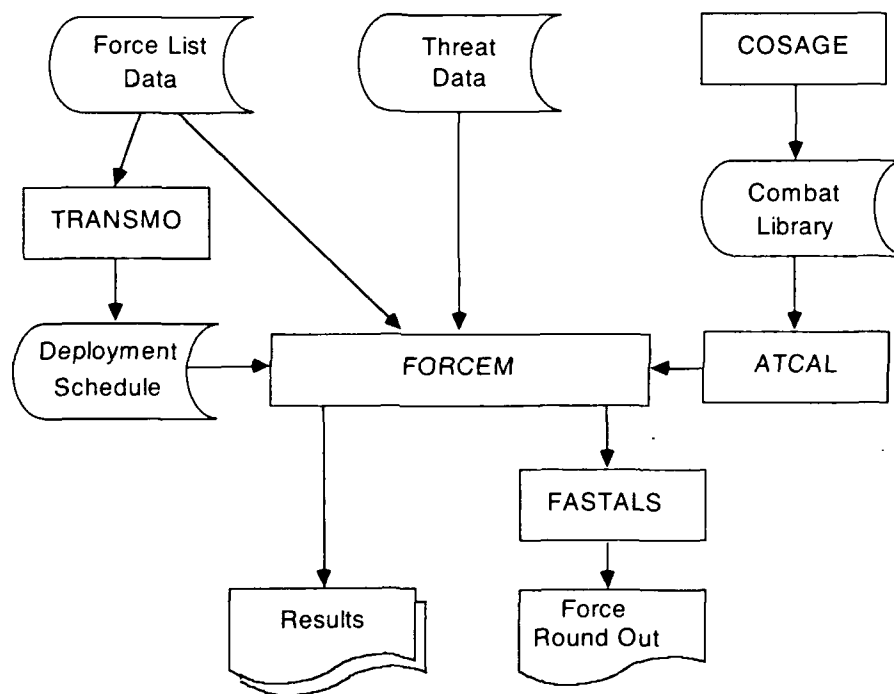


Figure C-1

personnel and materiel, which generates the combat samples needed by ATCAL.¹⁰ Other entries in the Figure indicate input and output data.

c. Temporal relationships.

(1) Linkage is an important aspect of FORCEM. In the original concept of the Army's model hierarchy, FORCEM was to use the results of the Corps-level model, Corps/division evaluation model (CORDIVEM), to evaluate divisional combat, rather than containing its own evaluative routines. It was envisioned as parameter lists passing situation and results between the two models, much like uplink and downlink vectors of data pass between an earth station and a satellite, ergo the term linkage. Problems and the subsequent demise of CORDIVEM, however, forced CAA to use its own division-level model, COSAGE, to provide the necessary data from which weapon-on-target results can be calculated within FORCEM. (CAA has the Vector-in-Commander [VIC] model, which has replaced CORDIVEM in the AMIP.¹¹ Moreover, the process to link VIC results to FORCEM has been conceptualized, and is expected to be implemented by the Fall of 1988.)

(2) The last components in the environment are the pre- and post-processors that are significant elements in the preparation and analysis of FORCEM applications. Programs extract information from several Army data bases to create the force description input, and the deployment schedule of arriving troops. The Force Analysis Simulation of Theater Administrative and Logistics (FASTALS) model is particularly important for the engineer force structure.¹² It is a post-processor that performs force "round out", i.e., it develops a list of non-divisional engineer forces necessary to support the combat force. According to FORCEM's AR 5-11 charter, the model was to be capable of generating force requirements. Although much thought has been spent on how this might be accomplished, it is unlikely that anything but FASTALS will be used for the near future.

¹⁰Wartime Requirements for Ammunition, Materiel, and Personnel, Volume V, Combat Sample Generator User's Manual (COSAGE) (October 1982).

¹¹Gamble, Alan, and Richard Porter, *Vector-in-Commander (VIC) Documentation* (US Army TRADOC Analysis Command, White Sands Missile Range [TRAC-WSMR], June 1987).

¹²Force Analysis Simulation of Theater Administrative and Logistics Support Model (FASTALS), prepared for the US Army Logistics Center (Computer Sciences Corporation, April 1980).

7. Functional Processes. The easiest way to introduce FORCEM's functions is by showing its logic structure (see **Figure C-2**). From it, one can see that there are three major areas: situation development, C², and the activities that actually change the states of various model elements. These areas will be briefly discussed to present an overview of the model. The processing flow of the model parallels the chart in that it generally cycles each period from left to right across the functions.

FORCEM's FUNCTIONAL STRUCTURE

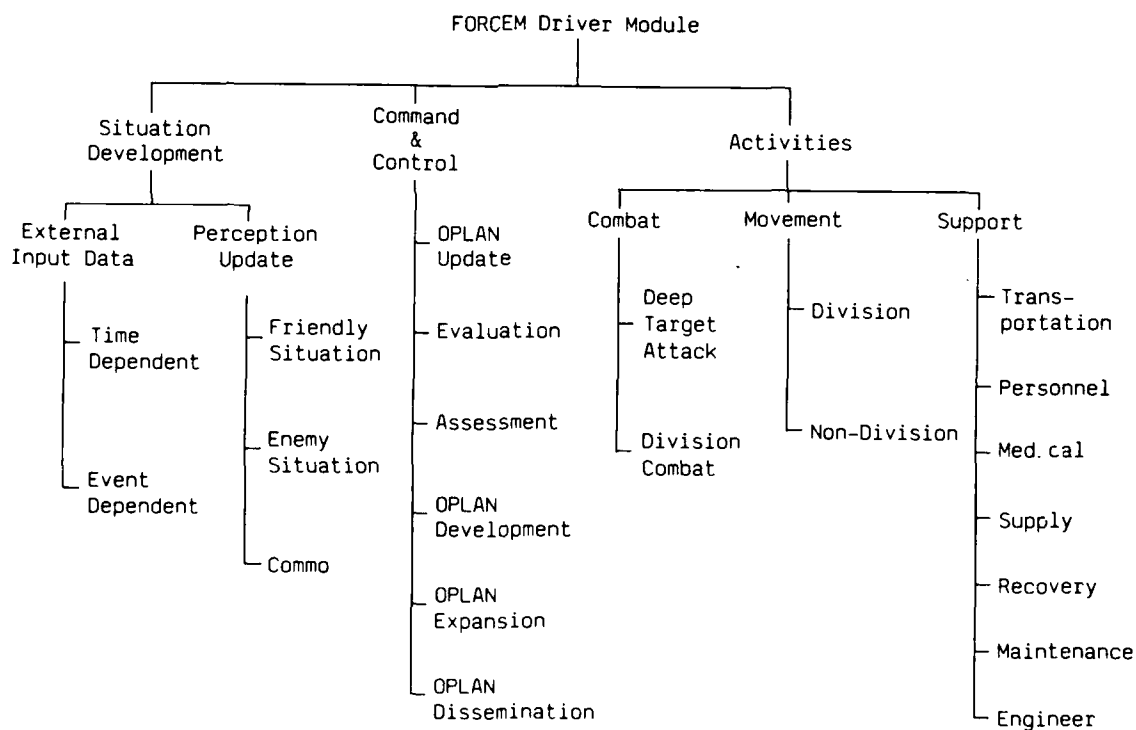


Figure C-2

a. **Situation Development.** Each time-step begins by checking the input files for unit and supply arrivals or externally directed events (such as port or air base attacks). This is followed by the gathering and processing of intelligence information and the transmission of that information among the headquarters' units, as part of building a perception base. Information about enemy forces is collected by sensors owned by C² units. Communications between units are handled through messages, which can be delayed if traffic exceeds stated inter-echelon channel capacities.

b. **Command and Control (C²).** The C2 process examines the situation at the echelons above division (EAD), i.e. Corps, Army, and theater headquarters, prior to making decisions affecting units and resources.¹³ Decisionmaking is automated and is a function of hard-wired decision rules and various other control parameters defined by input variables that set thresholds, ratios, or ranges against which the rules are evaluated.

c. **Activities.** Whereas information is assimilated and planning is developed in the other portions of FORCEM, most operations occur at the activity level. Units are moved depending on various objectives for forward area troops, the destination for units arriving in theater, and layouts for units subordinated to C2 units.¹⁴ Combat occurs at several levels: at the maneuver-unit level; in the full range of roles for air war; and in the deep strike capability of EAD artillery and surface to surface missiles. The latter two comprise the fire support function.¹⁵ And last, are various activities in the CSS area.¹⁶ Conceptually, the engineer submodule appears under CSS although it would be relatively independent of other CSS modules.

8. **Units.** Within FORCEM the "unit" plays a crucial and pervasive role. In an effort aimed at uniformity and reduction of data structures, a decision was made to use a single template for all units. It is important to understand the direct and indirect use of FORCEM units. Figure C-3 shows the

¹³Metzger, James J., *Command and Control in the Force Evaluation Model* (CAA, 14 January 1986).

¹⁴FORCEM Movement (CAA, 13 March 1986).

¹⁵Byrne, P. C., *The FORCEM Fire Support Module* (CAA, May 1986).

¹⁶FORCEM Combat Service Support (CAA, 20 February 1986).

FORCEM UNITS

Unit Types	Echelon Level			
	Theater	Army	Corps	Division
Command and control	x	x	x	
Support commands	x	x	x	x
Artillery	x	x	x	
Intelligence	x	x	x	
Communications	x	x	x	
Engineers	x	x	x	
Air defense	x	x	x	
Divisions				x
Allied Tactical AF (ATAF)	x			
Personnel pools	x	x	x	x
Equipment Pools	x	x	x	x
Air bases*	x			
Convoys (personnel)	x	x	x	x
Convoys (supply)	x	x	x	
Rail	x			
Barge	x			
Ports (air & sea)	x			
POMCUS (sites)			x	

*Air bases are subordinate to ATAF units at theater level, although they may be located anywhere.

Figure C-3

kinds of units and the echelons at which they can occur within the model. From the table, one can see that FORCEM uses units for many things. They range from the usual organization of men and equipment (e.g., divisions), to representing installations (e.g., prepositioning of materiel configured to unit sets [POMCUS] "sites" and Equipment Pool "depots"), and even convoys. FORCEM's intelligence, attrition, and effectiveness procedures were designed to process only units. Non-unit FORCEM elements, such as the LOC network, are consequently not acquired as targets or attrited.

9. Simulated Terrain and Physical Environment. The theater representation in FORCEM is composed of two components: the terrain grid; and the LOC networks. The system is unique to FORCEM. It characterizes an area cell (the dimension can vary -- early FORCEM applications used squares with 30 km sides,

recent ones use 10 km) by a list of eight directional vectors (north, north-east, east, etc.) indicating the predominant type of terrain encountered along the vector. The terrain type is then used to modify the inherent movement rate of a unit as it moves along one of the vectors. The LOC networks (road, canal, and railway) are implemented in a similar fashion (i.e., by directional vectors) except that instead of terrain types, the presence of road, railroad, and waterways is defined. (See Annex E for a more detailed discussion of these items.) The vector-based terrain representation focuses on movement rather than unit environment. Terrain appears to have no influence on unit postures. So any inherent advantage in holding a river line or establishing a position in terrain favorable to the defense is not considered. To a limited degree, however, a tenuous terrain contribution can be attributed to the line of sight and trafficability considerations inherent in the combat samples generated by COSAGE.

III. ANALYSIS OF ENGINEER REPRESENTATION

10. Theaterwide Engineering. In determining what is desired, it is useful to review the role of engineers throughout the theater. We will start with a broad overview. Figure C-4 shows the priority ranking of task categories for low-resolution models obtained from a survey of army modelers, engineers, and maneuver commanders. The details of this survey are discussed in Annex F. To help analyze the theaterwide task requirements for FORCEM, ESC used this task ranking as a starting point to develop a more detailed list of tasks by location throughout the theater (see Figure C-5). To allow a cross-walk between the priority order in Figure C-4 and the area groupings in Figure C-5 each task category in Figure C-4 has been given a letter code; and the tasks in Figure C-5 are followed by the letter of the category to which they belong. The actual entries in the table show the types of engineer tasks that occur within the applicable functional category. This list establishes the functions that are candidates for inclusion (either explicitly or implicitly) in FORCEM. The areas establish a framework that is directly relatable to the scope of various Army models: CASTFOREM is concerned with the brigade forward area; COSAGE is division sized; VIC looks at everything up through the corps; while FORCEM's scope includes the entire theater, but with particular attention to the communications zone (COMMZ). There is a natural bifurcation of engineer tasks into those that modify or deal with the terrain, and those that deal with facilities. It parallels the missions that engineers have in CS and CSS. Engineer work in the brigade and division areas, i.e., the forward combat zone (FCZ), generally deals with terrain modifying tasks. (Note that we will refrain from discussing the scores of actual tasks that comprise each of our listed functional categories. They are fully discussed elsewhere.)¹⁷ As one moves from front to rear in the theater, the focus shifts from the terrain to the facilities necessary to sustain the war effort. In fact, the repair, maintenance, and construction categories in the COMMZ comprise what is generally called sustainment engineering. The ability of CSS units to conduct rear area sustainment operations as well as move, clothe, and shelter troops, is

¹⁷*Mobility*, FM 5-101 (January 1985); *Counter Mobility*, FM 5-102 (March 1985); *Survivability*, FM 5-103 (June 1985); *General Engineering*, draft, FM 5-104 (April 1985).

LOW-RESOLUTION MODELS -- OVERALL TASK RANKING

Letter Code*	Task Categories Sorted in Priority Order	Priority Ranking (%)
<u>Vital Task Group</u>		
A	Install linear obstacles	8.9
B	Prepare fighting positions for direct-fire systems	8.8
C	Airfield damage repair	8.1
D	Maintain main supply routes	7.8
E	Prepare positions for indirect-fire & other systems	6.9
F	Port & waterfront facilities construction & repair	6.8
G	Site preparation & maintenance for CS & CSS units	6.7
H	Breach obstacles in the assault	6.5
I	Rear area facility rehabilitation & maintenance	6.4
<u>Critical Task Group</u>		
J	Forward airlanding facility preparation & maintenance	6.1
K	Conduct river crossing operations in the assault	5.8
L	Install point obstacles	5.6
M	Pioneer trail preparation & maintenance	5.5
<u>Essential Task Group</u>		
N	Improve river crossing sites for follow-on forces	4.7
O	Improve assault breaches for follow-on forces	4.0
<u>Necessary Task Group</u>		
P	Other (engineer raids)	1.2

*The letters are assigned to simplify the crosswalk between the task categories used in the survey covered in Annex F and the task break down discussed in this annex.

Figure C-4

ENGINEER THEATERWIDE TASK RESPONSIBILITIES

Functional Category	Brigade Forward Area	Brigade/Division Rear/Area	Division/Corps Rear/Area	COMZ AREA
Mobility	Assault/deliberate (H)* breach	Replace assault bridging (N)	Replace tactical bridging (N)	LOC bridging (D)
	Counter obstacle (H)	LOC bridging (D)	LOC bridging (D)	MOB BDR (D)
	Assault bridging (K)	Combat roads (M)	MOB BDR (D)	
	Combat Trails (M)	Forward aviation (J)	Forward aviation	
	Forward aviation (J)	Clear minefields (O)		
Countermobility	Combat demolitions (L)	Obstacle preparation (A & L)	Reserve targets (A & L)	Reserve targets (A & L)
	Anti-tank ditches (A)			
	Minefields (A)	Reserve Targets (A & L)		
Survivability	Other obstacles (A & L)			
	Fighting positions (B)	Protective emplacements (E)	Protective emplacements (E)	Protective emplacements (E)
	Protective emplacements (E)	- CPs	- CPs	- CPs
	Strong point preparation (A & B)	- Indirect fire positions	- LSA	- LSAs
	Deception (F, G, I, & J)	- ADA	- ADA	- ADA
Sustainment Engineering Damage Repair	Camouflage (F, G, I & J)	Protect support facilities (E)	- revetments	
		- LSA		
		Area damage control (I)	Area damage control (I)	Rapid runway (C) repair
Maintenance		Area damage control (I)	Area damage control (I)	Area damage (I) control
		LOC/MSR maintenance (D)	LOC/MSR maintenance (D)	RPWA
Construction		Develop LSAs	Facility renovation (I)	POL facilities (G)
			POW facilities (G)	Port construction (F)
			POL facilities (G)	USAF facilities (I)
				Supply
				Maintenance
				Medical
				Reception
				Camps

dependent upon engineer support. The "ideal" engineer module would address all the listed activities to simulate the breadth and amount of engineer work. Such an "ideal" version is, of course, realistically unattainable given the limits and level of detail of a theater model. The challenge then is to adapt engineer representational needs within FORCEM's present design, components, and computational limits.

11. Needs of the analytic community. What is FORCEM's purpose? As was indicated previously, FORCEM was designed to become the Army's principal theater-level war game, having the ability to test the adequacy of and identify the shortfalls in the Army's combat and support mix. While it has been used successfully on several studies, FORCEM has not reached the functionality directed by AR 5-11. Originally, FORCEM was to support both capability and requirements analyses, relying on the division/corps results from CORDIVEM. At this time, it operates as a capabilities model that relies on division-level combat samples from COSAGE, and on FASTALS to round out those portions of the force, including engineers, which are not represented in FORCEM. CAA is constantly improving FORCEM, and presumably it will eventually attain its targeted functionality. Thus, it will be used for both program and budget force analyses and eventually force design. At that time, its use will run the full gamut of studies conducted by CAA: OMNIBUS, Total Army Analysis, and war materials estimation. In those applications, FORCEM should not ignore the important, and in some cases, vital role of engineers, or other Army branches.

12. Compare Actual versus Desired Level of Engineer Play. CAA does not currently, nor is it likely to use, the engineer submodel developed by CERL. Thus the need to compare engineer representations may at first seem academic, because engineers are not currently represented in FORCEM. Engineers are, however, treated in the models that currently supplement FORCEM. To understand where engineer play would fit, it is important to compare FORCEM's actual and desired software environments.

a. Present Representation. Figure C-6 summarizes where and which engineer functional groups were primarily to be modeled in the AMIP and how they actually are. It shows that not only are engineers not being played in FORCEM, but they are also underplayed in the models that supplement FORCEM, particularly in the FCZ. Of the many engineer tasks comprising CS, only minefields are included within COSAGE. FASTALS uses allocation rules to

estimate engineer forces at corps and below. Such a method is, however, divorced from the actual effects these forces might have on the battlefield. Engineer support levels in the COMMZ fares better in FASTALS, at least to the extent that they are based on estimated requirements. Engineer COMMZ workload

OPERATIONAL ENVIRONMENTS
(Engineer Task Representation)

	Theoretical		Current		
	CORDIVEM	FORCEM	COSAGE	FORCEM	FASTALS
Mobility	x	x ¹			
Counter-Mobility	x	x ¹	x ²		
Survivability	x	x ¹			
Sustainment Engineering (Division)	x	x ¹			
Sustainment Engineering (COMMZ)					
Repair		x		x ³	x ⁴
Maintenance		x			x ⁴
Construction		x			x ⁴

¹FORCEM would play activities that are in the corps rear (e.g., LOC bridging, army airfields, digging in ADA units, etc.).

²COSAGE only simulates minefield effects (delay and attrition).

³FORCEM engineer logic allows repair of ports, air bases, and POMCUS sites, but CAA has elected not to exercise engineer play.

⁴See discussion of FASTALS.

Figure C-6

in FASTALS is based on 23 task categories, which are functions of 13 workload parameters (see Figure C-7). These tasks, however, do not represent all engineer COMMZ tasks. It is difficult to distill engineer's varied workload into just a few broad parameters. How many miles of road or railroad are "in

FASTALS ENGINEER WORKLOAD PARAMETERS

Workload Parameter	FASTALS Task (and number)
1 Miles of road*	Repair of roads (1) Repair of road bridges (2) Maintenance of roads (20)
2 Miles of railroad*	Repair of railroads (3) Repair of railroad bridges (4) Maintenance of railroads (21)
3 Miles of pipeline*	Repair of pipeline (5) Maintenance of pipeline (22)
4 Dry cargo & unit equipment through port per day	Repair of ports (6)
5 Dry cargo (Class V)**	General supply storage (10)
6 Class V supplies stored**	Ammunition storage (11)
7 Class I stored**	Refrigerated storage (12)
8 Class III stored	POL (bulk) storage (13)
9 EPWs	POW camps (14)
10 US Army non-divisional population	Administrative space (9) Troop camps (8) Dispensaries & clinics (17) Maintenance shops (18)
11 Replacements thru camps/day	Replacement camps (19)
12 Fixed bed requirements	Hospitals (16)
13 Manual computation	Repair of Army airfields (7)
*Miles in use **1000 Short Tons supplies	

Figure C-7

use?" Are only major routes included, or all routes? Where do supply class quantity estimates come from? While the process that arrives at these values may be credible, the danger of using too simplistic an equation jeopardizes the correctness of the estimate.

b. **Implications.** The omission of engineer capabilities and contributions at EAD in theater level wargames at CAA has ramifications throughout the Army. Engineers comprise 11 percent of the total Army TOE structure. Unlike most other branches, engineer activities range from the covering force areas, to the ports in the theater rear. Admittedly, it is difficult to model the effect of a minefield, or the result of not doing road maintenance. History is too replete, however, with evidence from many quarters showing the importance of such tasks and the often critical role engineers play. Accepting the contention that engineers should be duly represented in FORCEM, the following sections show several specific areas where effort should be directed.

(1) FORCEM contains code for COMMZ engineer repair tasks and engineer units. Up to now that capability has never been exercised in a study. Nor does it appear that the effort that went into confecting the existing engineer logic was anything more than a learning experience. The reason why is not because of something intrinsic to engineer, but because the structures used were inconsistent with the rest of FORCEM. This lesson must be considered when developing an improvement plan. In any case, the result is that although engineer units can be present in the model, they are not and thus don't explicitly effect play in any way.

(2) Although engineers at EAC are not played in FORCEM, force planners must still quantify them. FASTALS currently satisfies this need; however, the force round out process's use of a few general workload parameters, and particularly of allocation factors and set asides, diminishes the dynamic contribution of engineers. Nor does it indicate what the effect of non-support means to the successful conduct of the war. Moreover, FASTALS does not directly consider some vital engineer tasks that have important resource and force effectiveness impacts.

(3) FORCEM's primary area of interest is at EACs. As said earlier, to be able to concentrate its attention there, it relies on combat samples for combat results. Initially, FORCEM was to depend upon CORDIVEM for division and corps information on combat outcomes. COSAGE was substituted but

only operates at division-level, and only considers one engineer-related activity -- minefields, specified by predefined locations and seemingly independent of engineer troop availability. Setting aside, momentarily, the questions of how well COSAGE models FCZ engineer tasks and FORCEM (or FASTALS) models COMMZ tasks, there is a gap in engineer workload representation between COSAGE and FASTALS, principally in defining engineer workload for engineer units at EAD. This omission serves to ignore, in particular, the role of engineer corps battalions (doctrinally having as many as three battalions, over 2,000 non-divisional engineer troops, for every combat division) to effect the conduct of the war. First, even if FORCEM's C² logic assigned corps engineer battalions to the direct support of a division (similar to allocating artillery support), which it does not do, ATCAL's evaluation would be unaffected. And secondly, there is no mechanism, implicit or explicit, within FORCEM that considers engineer activities in the corps' rear area. Engineer activities in that area have a direct impact on ADA survivability, POL storage, forward aviation, etc. Presuming availability without comparing engineer requirements and capability could very well bias results.

(4) The critical importance of sustaining USAF sortie rates in the face of enemy attacks is not realistically played in FORCEM. Air base damage in the model has no effect on air base operations; and USAF personnel, in particular base civil engineers, are not included. A US Army engineer mission is to assist USAF engineers when damage or beddown requirements exceed USAF capability. The beddown task, in particular, can be sizeable depending upon the theater being played.

(5) Further complicating the issue, is the need to consider host-nation engineer support (HNS). Estimating how much assistance US forces will receive from indigenous military or civilian engineers is part of US military planning.¹⁸ FASTALS includes an estimate of HNS in determining US engineer requirements. If engineer operations are injected into FORCEM, then HNS will have to be addressed either explicitly or implicitly.

(6) Since FORCEM is a symmetric model, the lack of engineer play applies as well to enemy capability. In a European scenario, PACT forces do not have to worry about seaports and the extended oceanic LOCs that confront the US or North Atlantic Treaty Organization (NATO) commander. But they

¹⁸Army Force Planning Data and Assumptions, FY 1988-1997 (DA, August 1987).

do have to worry about keeping their air bases operational, and maintaining their own LOCs. And even more than NATO, they must worry about mobility and sustaining the offensive in consonance with their doctrine. If FORCEM professes to emulate an air/land battle doctrine, then it should play the effects of both deep attacks and the enemy's ability to contend with them.

13. Recommendations. FORCEM is continually evolving and moving toward the operational capability outlined in the AMIP. This presents somewhat of a problem since, to a degree, FORCEM is a moving target. Which combat sample generator should one plan around? Should it be the limited, division-level COSAGE or the more expansive, corps-level VIC model? Does one also assume that FASTALS' tasks will eventually be brought into FORCEM? And most importantly, will CAA's own ongoing development of FORCEM make any engineer code submissions moot? ESC recognizes these concerns and has adopted an approach which looks as much at FORCEM as it does at simulating engineer activities. Unlike CERL's focus, which appears to be a continuation of its previous FORCEM work, ESC has chosen to frame its recommendations in more systemic terms, treating the model as an environment and engineer work as classes of tasks rather than many isolated pieces.¹⁹ The recommended improvements have been divided into two parts: the first deals with features that must be added to FORCEM to realistically represent engineers; the second looks at several FORCEM constructs which, if changed, would greatly influence how engineer enhancements are implemented. ESC believes that its proposed structural changes to the model would enhance FORCEM as well as facilitate particular engineer-related additions.

a. Engineer enhancements. Engineer actions have several dimensions. Where do engineers operate? What do they do? Who does it? What is

¹⁹ESC's findings and recommendations essentially corroborate CERL's views on engineer representation. CERL breaks improvements into groups of tasks to be implemented in three phases: the first addresses construction and repair at installations or facilities that can be tied to either FORCEM units or the logistic network without major modifications; second, mobility, counter-mobility, and survivability tasks would be introduced into the corps rear, and direct support to divisions would be examined; and finally, FASTALS tasks that were not addressed in the prior phases, USAF and Army emergency repair missions, and hospital support would all be included. The difference between the September 1987 and December 1987 proposals was CERL's own concern over the relevancy of implementing tasks without also including the effects of their non-performance.

the result? These questions must all be answered in the model if it is to realistically emulate engineers. For our purpose, they have been broken into the following categories: terrain, installations, tasks, units, and effects.

(1) Terrain. To effectively model many engineer operations, there must be a realistic treatment of terrain, including the logistic network. Much of combat engineer support involves terrain modification. History shows that combat results are inextricably bound to the terrain, whether engineer modified or not (e.g., Kursk, Monte Casino, North Africa, and Market Garden). We have noted that COSAGE division samples implicitly include minefields, although irrespective of engineer capability present in the division or corps. Otherwise, obstacle and barrier systems, whether existing or planned, forward or rear, are not included in FORCEM. Terrain as a whole is essentially a non-factor, beyond influencing movement. The combat samples generated by COSAGE use a statistically "averaged" terrain sample, which is primarily concerned with representing line-of-sight. On the other hand, even if terrain did affect unit postures or combat results, FORCEM's limited terrain representation could not supply meaningful input. Each terrain vector in FORCEM is coded according to a dominant terrain feature which is used primarily as an index to a movement rate table. The LOC networks are similarly represented. Enhancements are necessary to represent the engineer activities at EAD, associated with movement. At the very least, modifications, both temporary (simulating minefield creation and clearing) and permanent (destruction of a major bridge, upgrade of a road to MSR standard), to vector and network members (to effect movement rates) must be supported. Capacitating the LOC networks should also be considered in order to better estimate the effects of damage and maintenance needs as well as bottlenecks and overload. These changes will not effect combat engineering (unfortunately it appears that for as long as FORCEM is dependent on COSAGE the ability of engineers to influence the division battlefield will be negligible), but they will at least better reflect the important engineer support of LOCs and movement in general.

(2) Installations. With the bulk of COMMZ engineering concerned with facilities, FORCEM needs to represent the sustainment base, and operations associated with it. Currently, FORCEM models three types of

installations: ports, air bases, and POMCUS sites.²⁰ It does not, however, adequately represent operations at those installations. Nor can it be said that the three adequately describe the entire sustainment base. Units are played in FORCEM (such as personnel and supply pools) which imply the existence of depots, troop camps, maintenance shops, and hospitals, but there are no installations. Since the units and the functions they perform implicitly rely on the existence of supporting installation and facilities they should be included in the model. The presence of, or requirement for, an installation might be dictated by several different means: as a preexisting asset, by external direction (e.g., logistics-over-the-shore operations [LOTS]), or as an internal event (movement of a support command might demand a new depot to be built). The size of the installation can probably be expressed in either absolute terms (square feet or barrels of storage) or using a single surrogate measure such as beds, number of troops, or tons of storage. Engineer construction, repair, and possibly even maintenance tasks could be associated with installation types through tables or piecewise continuous curves. With installations explicitly represented, damage could be calculated explicitly rather than by using unit casualties as a surrogate measure. This would make damage a function of installation characteristics (not of the units that happen to be there) and threat capability. It would also better support engineer repair workload and resultant installation capability estimates. Ideally, installations would be best served if defined as separate entity classes, rather than contorting them into the unit framework (see section on FORCEM improvements).

(3) Engineer tasks. Better representation of terrain and installations will provide the foundation for identifying and quantifying engineer workload. First, the representation of tasks should be standardized. Normally, engineers express resource requirements for terrain modifying tasks (including bridging and minefield laying) in terms of squad and equipment

²⁰The engineer definition of an installation is "...a group of facilities in the same vicinity that supports particular functions..." (AFCS Design Manual [US Army Engineer Division, HNDM-1110-1-4, 1 September 1980], p. 1-3). Now there is only one type of facility explicitly represented in FORCEM -- runways. Realistically, facilities are probably below FORCEM's resolution; representing installations and LOCs is more in keeping with the model's current level of detail.

hours.²¹ Facility, i.e., installation-related tasks, generally use work estimates derived from the several services' facility component systems,²² which express construction, repair, and maintenance tasks in terms of average daily hours of required horizontal, vertical, and general engineer skills.²³ While the skill and equipment distinctions are real, they introduce resolution inconsistent with the intended level of detail in FORCEM. More appropriate would be task requirements that remain related to the magnitude of the activity or size of the installation, but expressed in terms of amount (hours per cycle) and duration (number of cycles) of engineer support. A second component of task representation is identification. Rather than have engineers search for jobs, it seems more efficient for a task, whether digging in an ADA unit or repairing an air base, to be identified at the time the event occurs, and to be placed in the task queue of an engineer or C² unit. For the purpose of discussing particular workload categories, engineer tasks have been divided into combat and COMMZ area groups. An earlier discussion of engineer tasks indicated that this is but one of several different ways tasks could be partitioned.

(a) Combat zone. FORCEM's reliance on division combat samples means that most deficiencies in combat engineer representation cannot be mitigated by making changes to FORCEM itself. Engineer improvements within FORCEM will not reach the FCZ area, where results from COSAGE are currently used. If it is accepted that engineers should be one of the factors in the combat samples, the question then becomes how this can be accomplished. Besides modifying COSAGE, there is another alternative -- VIC. This model is now on CAA's VAX 8600, and the agency is studying the model and the prospects of using it in lieu of COSAGE. Engineers are explicitly played in VIC, and improvements and additions are being pursued.²⁴ If CAA's evaluation indicates VIC will become the combat sample generator, then improving engineer play in COSAGE may become a moot issue. On the other hand, since FORCEM has been designed around divisional combat, it seems likely that even if VIC, despite

²¹Engineer Assessment, Korea: Forward Combat Zone Analysis (ESC, July 1986).

²²Army Facility Component System, Temperate Zone (TM 5-301-1).

²³Engineer Assessment, Korea: Communications Zone Analysis (ESC, September 1987).

²⁴See Annex B, this report.

its more expansive corps-level scope, succeeds COSAGE, samples will remain structured around divisional play. While it makes sense to defer FCZ consideration until VIC arrives, combat-related tasks arising in the corps rear can, and should be added to FORCEM now. Combat engineering tasks of mobility, countermobility, and survivability occur at EAD. Typical tasks include: digging in air defense artillery (ADA) units, rear obstacle preparations for the defense, obstacle clearing for the offense, LOC repair, and forward aviation support. Note that these tasks involve both terrain and installation related tasks. Some of the tasks can be readily tied to events presently within the model. An example is the need to prepare positions for an ADA unit. Tasks such as tactical airfield construction and constructing defensive obstacles, however, appear to be beyond the present decisionmaking ability of FORCEM, and would necessarily be the result of offline analysis.

(b) COMMZ support. At the very least, FORCEM's engineer representation should adequately simulate operations at the level of particular emphasis in the model -- EACs. Engineer tasks at EAC primarily support the construction, repair, and maintenance of the sustainment base. Realistically, representing these tasks involve several needs: determining installation and facility requirements, calculating construction resources, estimating damage and maintenance, and assessing the impact of reduced or inadequate installation facilities. This is not an easy problem and is large enough to require substantial models of its own.²⁵ Within FORCEM, engineer tasks in the COMMZ will naturally be associated with installation needs. As with CS taskings, it will probably be easier to identify the task, in some form, at the change of state time by logic that applies to that class of installations. The notice could then be either kept at the installation or passed to a unit.

(4) Engineer units. Engineer unit configuration is dictated by the structure permitted by FORCEM and the representation of engineer tasks. Engineer units vary widely in specialty, capability, and composition. Some units have very definite tasks associated with them. A port construction company operates essentially at or near the shore of a port or LOTS site, while a pipeline company is specially trained and equipped to pursue its trade. Realistically, the level of detail involved in modeling such special

²⁵ *Simulated Engineer Assessment of the COMMZ (SEAC)* (ESC, June 1988).

unit capabilities is not commensurate with the rest of FORCEM. Nor are the common expressions of engineer unit capabilities (i.e., squad and equipment hours for combat tasks and skill hours for facility-related work). In keeping with the proposed FORCEM task definitions in terms of man-hours, engineer unit capability also should be expressed as the number of hours available during a FORCEM time slice (currently 12 hours). This also would satisfy the second predicator of engineer unit structure within FORCEM -- CAA's present or future (see next section) definition of units.

(5) Effects. The effects of accomplishing or not accomplishing engineer tasks are as fundamental to representing engineers as is the inclusion of engineer units or the identification of installations and terrain associated tasks. Engineer operations should not be isolated from the other processes within FORCEM. The reason why there is an Engineer Management Improvement Program (EMIP) is that engineer contributions in the FCZ and COMMZ have heretofore gone unrecognized in combat models. This is undoubtedly because of both the focus on weapon systems and strictly combat forces and to a degree on the fact that engineer effects do not fall into one neat little package. Engineers can slow up the enemy as well as destroy them. They can permit friendly forces to move faster and to places otherwise denied to them. Figure C-8 attempts to show the disparate candidates an engineer modeler could use for measures of effectiveness (MOEs) for various tasks. The effects in the table are not even meant to be exclusive; a minefield can be used as much to delay or reduce movement, as to directly kill enemy vehicles and personnel. The effects are even harder to quantify. Nonetheless, a strict criteria for including engineer tasks should be that an MOE also be included. Data and logic that do not influence the outcome of the simulation are mere clutter and should be avoided. Representing effects, however, means that other FORCEM processes and elements must reflect the impact of inadequate engineer support. For example, air base sortie generation and LOC capacity are presently unaffected by model events. To implement the mechanism to allow installation facility status to influence their operations, new logic and data would need to be added, not to engineer units or tasks, but to air bases or LOC routines and data. Classification of initial damage repair must be addressed (all

SAMPLE OF ENGINEER ACTIVITIES AND ASSOCIATED EFFECTS

Area	Engineer Activity	MOEs
FCZ	minefield emplacement	casualties
	increase friendly mobility	movement rate
	decrease enemy's mobility	movement rate
	build defensive positions	casualties
Corps Rear	improve survivability	casualties
	logistic network	supply capacity
	prepare obstacles	movement rates
COMMZ	build/repair ports	resupply capacity
	build/repair air bases	sortie rates
	pipeline construction	capacity
	maintain LOCs	capacity

Figure C-8

repairs at an air base need not be made to restore maximum operational capability) as well as its effect on reducing an installation's operational capability.

b. **FORCEM improvements.** Designing and implementing code which will achieve much of what has been described, is not a trivial undertaking. Changing any model, much less one as complex as FORCEM, is usually easier said than done. During its review, however, ESC noted that the form of several major FORCEM elements and conventions, greatly determine how engineer operations will or can be represented. In their present forms, these features will probably require the engineer modeler to use various indirect means to achieve results. Since FORCEM is continually being improved, however, it should be possible to retool portions of the model. ESC proposes two FORCEM improvements that would not only facilitate engineer modeling, but also have value to processes throughout the model.

(1) **Terrain.** ESC has indicated that FORCEM's terrain representation would have to be augmented to support representation of some engineer tasks and associated effects. The present terrain structure essentially defines several networks which facilitate movement calculations. Internally it is represented by several two-dimensional integer arrays; array cells contain the vector characteristics stored in packed format (i.e., the eight directional codes are stored as an eight digit number with the first digit

associated with northeast, the second with east, etc.). No other data is endemic to a grid cell. A cell appears not to know that it contains air bases or ports. To find out what units (remember that ports are pseudo-units) might be in a cell, a unit list must be searched with each unit's location compared against the cell's to see if it is in that cell. This is efficient as long as the lists remain relatively short. If obstacles, LOC capacities and damage, and installation data are all placed in such lists, the length of the list and therefore the processing time could increase dramatically. ESC is concerned that if the engineer submodel is perceived to take too much time or space, that it runs the risk of being deactivated, as have other attempts to model engineers. Although CAA has no plans to change the map square, vector-based terrain representation, ESC feels that FORCEM's terrain representation should be enriched to better support terrain related actions. A viable alternative might be to make it entity-based. This would enable significant physical and man-made terrain features as well as units, installations, LOCs (including pipelines), obstacles, and other pertinent data to be directly associated with a cell. The drawbacks are increased memory requirements and the need to make modifications, some significant, to existing routines. The advantages are a unified terrain structure, improved means of inserting, removing, or locating objects in a cell, and more realistic procedures and effects (engineer operations, combat attrition evaluation, target acquisition, intelligence, chemical, nuclear, etc.).

(2) Units. The FORCEM "unit" stricture should be reduced. In trying to be everything to every element in as large a model as FORCEM, the unit has accumulated overhead that instead of supporting enhancements, impedes them. Adding a new model element that has people, assets, or can be targeted, means it has to be a unit and have the same attributes that every other unit has. If it requires a new attribute, then all other units acquire it as well. This has become inefficient and monolithic.²⁶ (A more efficient and powerful means to accomplish the intent of the unit is found in the hierarchical data

²⁶An example is aptly illustrated by CAA's rejection of CERL's engineer module. In trying to fit its design into FORCEM, CERL used the attribute list not for equipment but for subordinate units. Since SIMSCRIPT does not identify data typing inconsistencies, CERL's artifice guaranteed runtime errors. With all entities accessible to all procedures, changes must be reviewed across the entire model.

structure, common to object-oriented languages, which provides a means to selectively combine general and specific entity attributes and procedures.²⁷⁾ While increasing the number of different model element types could require associated changes in some processes (targeting and attrition among others), the looser coupling could make model additions and modifications easier.

c. **Summary.** The previous paragraphs have described the general requirements for modeling engineers in FORCEM. **Figure C-9** summarizes the tasks, FORCEM elements, and effects that comprise the engineer modeling program. The first task, improving combat engineering, involves FORCEM only to the degree that an improved combat sample generator would accept terrain and engineer parameters. The next three tasks are associated with activities in the corps rear area. The remaining tasks, largely occur in the COMMZ, but, depending on actual installation location, could fall within corps boundaries. Other than grouping the tasks loosely according to theater area, there is no other meaning to be ascribed to the order of the tasks in the table. The reason for this is the mutuality of elements and tasks. If FORCEM's terrain representation is being changed to accommodate more realistic LOC play, how reserve targets might be implemented should also be considered. This is because both deal with the terrain and movement effects. Similarly, exploring better representation of installations effects many of the listed tasks. Rather than looking first at improving port representation, and then at supply depots, the modeler should be looking at the characteristics all installations have in common, and the specific features that sets them apart. A well structured solution will ultimately be more efficient and adaptable, than something designed piecemeal. Thus the entries in **Figure C-9** represent an agenda, rather than a step-by-step approach. Some changes, although viewed necessary, are dependent on things beyond the control of the engineer modeler. If VIC were not to replace COSAGE, then representing engineer support to division combat would not improve. If the impact and cost of changing terrain and LOC network representation in FORCEM is prohibitive, then associated engineer tasks will have to use less satisfying indirect means.

²⁷Two examples of which are ADA: *ADA Programming Language* (ANSI/MIL-STD-1815A, 22 January 1983); and SIMULA (Franta, W. E., *The Process View of Simulation*, North-Holland 1977).

FORCEM ENGINEER MODELING REQUIREMENTS

Engineer Task	FORCEM Element or Routine	Modeled Effects
Combat Engineering Mobility, Countermobility, and Survivability	Division Level Analytic model of division operations	Implicit in casualty, movement, and expenditures
Reserve targets ⁴ (i.e., partially emplaced rear area obstacles)	Exogenous event associated with terrain cell(s)	Modifies terrain
Forward Aviation	Corps C ² unit	Affects Army's fixed and rotary wing sortie generation
Protective emplacements	ADA and C ² units	Reduced damage and casualties
Damage repair to existing FORCEM installations ¹	POMCUS, Air base (MOBs), and Ports (APOD & SPOD)	Reduced operational capability
LOCs ² damage repair and maintenance	Roads, Railroads, Canals, Pipelines	Reduced logistical thruput
USAF beddown and restoration	Air base, Ports (APODs)	Reduced sortie generation, or personnel and supply handling
Damage repair to new FORCEM installations ³	Logistic installations (hos- pitals, depots, troop camps, etc.)	Reduced unit processing capability
Austere facility construction	Logistic installations	Reduced unit processing capability
Special construction projects (e.g., LOTS)	Exogenous event for any FORCEM installation or LOC object	Adds new capability
Stockade & EPW	C ² unit	No effect ⁶

- ¹POMCUS, air bases, and ports representations will be improved.
- ²All LOC types will be improved (possibly to include bridges).
- ³New installations associated with units now in FORCEM.
- ⁴Implies an improved terrain representation.
- ⁵Anticipates using VIC's more detailed engineer representation.
- ⁶Included for FASTALS compatibility.

Figure C-9

IV. ANALYSIS OF MODIFICATIONS

14. Modeling Approach. The design of a new engineer sub-model is largely constrained by the existing design of FORCEM. Only if the optional FORCEM improvements that ESC identified were adopted, would a great deal of flexibility be gained. The specification and design of a new engineer sub-model must therefore balance the constraints imposed by the implementor/manager (CAA) and the interests of the users (both force designers and the engineer community). Structuring, simplifying, shifting (i.e., to another model), and substituting are activities performed by modelers to make a problem tractable. There is no one solution. But a solution that is never perfected (i.e., never becoming a standard FORCEM feature), should not be allowed to happen. As to what programming approach will be adopted in a FORCEM engineer submodel, that should be left to the developer, although always subject to the conventions used in FORCEM. While the engineer modeler should have some latitude, there are several points that do need to be offered as guidance.

a. Capability v. requirements. As stated earlier, FORCEM presently operates as a capability model, although its future ability to run as a requirements model has not been dismissed. How requirements might be handled remains to be solved. Rather than speculate on any future undefined feature, the engineer modeler should concentrate design efforts for the present environment.

b. Implicit v. explicit. Tasks, engineer capabilities, and effects can all be represented in varying levels of detail and form. Implicit treatment very often is a euphemism for a simplified, offline, or surrogate treatment. An explicit element is just that -- a model process, datum, or event that is particularized. Ideally one would like to make everything explicit. The ability to do so and the benefits gained, however, often say otherwise. To do what it does, FORCEM blends both modes. Combat, for example, is implicitly accomplished using ATCAL to extrapolate among different COSAGE results. One must be wary, however, when implicit is used to ignore problem aspects. The engineer modeler should start with the idea that everything should be explicit, but be prepared to consider implicit representation depending upon circumstances.

c. Task origination. A follow-on to the previous paragraph is the question of how special engineer jobs are introduced. Unlike tasks that, at

least conceptually will be requested by existing FORCEM elements, such as digging in an ADA unit, or implied by doctrine, like assigning a Direct Support mission to an engineer battalion, some special engineering projects, while identified by the operations plan, have no triggering event. Emplacing rear area obstacles, building LOTS and air base facilities, and constructing a pipeline are examples of such projects. A separate event stream and routine are necessary to create the special project and follow its construction until it becomes viable.

d. **Prioritization.** Expecting that there will be periods when engineer capability is insufficient to meet demand, there should be a mechanism in place to categorize work into priorities. This could be done by using decision rules similar to other resource allocation processes within FORCEM, but may be more simply accomplished by using priority assignments. This would simulate the action of engineer planners in working with scarce resources. In fact, at the installation level, work might well be stratified according to importance, and the capability of the installation should be adjusted according to what work can be accomplished.

e. **Guidance.** To reduce the danger of being used inappropriately, and to avoid later criticism, a certain level of modeling discipline must be stipulated and maintained. Too often models are developed, but over time become far removed from the original designers. Whoever implements the new engineer submodel should not only develop code and identify data, but also prepare a user's guide that cross-references the structure and data of FORCEM that directly and indirectly affects engineer play.

f. **Interpretation.** Until the phased development runs its course, engineers will not be fully represented in FORCEM. The units and their capabilities, as the easiest items to implement, might all be present, but the tasks and effects that they will accomplish and create respectively, probably will not. Thus engineer and force planners should be cognizant of different mixes of workload and capabilities and not assume that the model improvements are in locked step. The underplay of engineer work could overstate engineer capability. Any analysis should either identify this possibility, or actually withhold engineer units that would be dedicated to absent task workloads.

15. **Ease of Modeling.** The "stillbirth" of CERL's engineer model for FORCEM, illustrates that changes or enhancements to FORCEM may not be facile. Modifications must be examined across the entire model to understand possible

impacts and unforeseen effects. (SIMSCRIPT's lack of strong typing, e.g., its inability to identify incorrect use of pointer variables, is a potential trap for novice and expert programmers alike.) Attaining adequate knowledge of FORCEM requires a considerable start-up investment, especially for someone outside of CAA's development team. In view of this, new software for FORCEM should be cleared with CAA at every stage of its development, since the implications of adding or changing code or data may not be evident.

16. Resources Required. Because the engineer modeler will need to become somewhat of a FORCEM expert, the time to develop and implement a working engineer submodel will take somewhat longer than if he were developing a stand alone module of comparable size. ESC estimates that one accomplished SIMSCRIPT programmer/analyst should be able to research, implement, and document the engineer model in 18-24 months. If, for example, CERL was given the job, one would expect that its familiarity with FORCEM would place it at the lower end of the range. In addition, but concurrent with code development, would be a 6- to 12-month analysis of data requirements. This would quantify engineer unit capability, task resource requirements, installation facility cross sections, installation and LOC damage and maintenance factors, and corresponding data for enemy engineer operations. Not addressed in these figures is any effort CAA might expend in modifying FORCEM, i.e. changing unit or terrain representations, or switching from COSAGE to VIC. Proposed changes to non-engineer routines and entities probably would not be done by the engineer modeler. Whether CAA would do it in-house or through outside parties, would be its prerogative. If FORCEM improvement options were pursued, the engineer timetable would necessarily be effected, not because it would take more effort to model engineers, but because of waiting for the modifications to finalize. Resources to convert and link VIC are also outside engineer modeling, despite having potentially great impact on combat engineering. Exploiting VIC engineer capability would, however, mean that decision logic allocating corps engineer assets would have to be included in FORCEM, whereas such code is presently absent and would be superfluous with combat samples from COSAGE.

17. Impact on FORCEM. The surest result of the proposals is that the model will require more memory, and take longer to execute. Truthfully, it is difficult to predict how much longer a model, as large and complex as FORCEM, will run if non-trivial changes are made. It is not like doubling the dimension of an array in a matrix multiplication program and estimating that it will

now take four times longer to run. A simulation program will be different for each data and event set. Since the engineer submodel will be adding data, introducing new code, and effecting the conduct of other existing routines and entities, it will mean FORCEM has more objects to create and manage, more processes to invoke, and more decision paths to follow.

18. Conclusions. Engineer contributions on the battlefield and throughout a theater are many and diverse. Those contributions are currently not being represented in FORCEM, although under the AMIP charter and as the Army's principal theaterwide model, they should be. FORCEM's special emphasis on simulating activities and effects at EAC, should include a minimum COMMZ engineering representation. Considering the role of theater wargames in force planning and programming, it is apparent why engineers seek equitable representation. While the sheer variety of engineer activities does present certain implementation problems, they can be modeled. In preparing its recommendations, ESC compared a list of engineer activities with both present and future FORCEM environments, to identify inadequacies. The result is a list of enhancements (see Figure C-9) that will serve as the basis for improved representation of engineers in FORCEM. Figure C-10 presents the range of possible EMIP strategies for FORCEM. The options run the gamut from doing nothing, to creating a new theater model (i.e., making it the be all requirements and capabilities model, subsuming the functions of both FORCEM and FASTALS). The extreme cases are of course undesirable and unlikely, respectively. Setting them aside leaves us with three plausible approaches. Option 2 simply trades VIC's better representation of engineer capability for COSAGE's. Since CAA intends to install VIC in Bethesda, this change appears to be a given. The adjustment in FORCEM to take advantage of VIC's more detailed division play (including engineers and terrain) should not be major. Although beneficial to engineer combat play, switching to VIC does nothing for engineers at EAD. FASTALS, as indicated, is still on line, but as a requirements model it does not measure the contribution or impact of engineers. Option 3, like option 2, includes VIC, but both models incorporate engineer enhancements.²⁸ ESC uses enhancements and improvements in the same manner that it has throughout this annex; enhancements are new model features or capabilities, while improvements are changes to existing model structures or processes.

²⁸See Annex B of this report regarding VIC.

ENGINEER MODEL IMPROVEMENT OPTIONS FOR THEATER LEVEL MODEL

Function	Model	Option 1	Option 2	Option 3	Option 4	Option 5
		status quo	Improve FCZ	Enhance ENGRS	Improve FORCEM	Redesign
Division Combat Simulation	COSAGE	*	o 	o 	o 	o
	VIC		*	E	E	E
Theater Model	FORCEM	*	*	E _C	E&I _C	o
	FORCEM. 2					N _{R+C}
Round out	FASTALS	*	*	*	*	o

* unchanged
 o old version
 E enhanced version
 I improved version
 N New model

R Requirements
 C Capability

Figure C-10

Enhancements to FORCEM would represent engineer units, workload tasks, and the data and routines necessary to measure engineer effects.²⁹ Option 4 adds FORCEM improvements to Option 3. The FORCEM improvements outlined by ESC would have general benefits as well as providing a more accessible structure for engineer enhancements. Note that FORCEM under both Options 3 and 4 only measure engineer capability; FASTALS is projected to still generate requirements under both, but the ability of the force to accomplish predicted engineer workload will be examined in FORCEM (options 3, 4, and 5). In terms of desirability, ESC would rank the viable options: 4, 3, and 2. It is thus ESC's conclusion that to adequately represent the contribution of engineers in FORCEM the following plan should be adopted: that FORCEM use division-level combat samples from the planned engineer enhanced version of VIC; that improvements be made to FORCEM's representation of terrain, installations, and units; and that the identified engineer tasks and effects be incorporated in FORCEM.

LAST PAGE OF ANNEX C

²⁹See Evans *ibid*.

ANNEX D

ENGINEER FUNCTIONAL AREA MODEL (EFAM)

ANNEX D

ENGINEER FUNCTIONAL AREA MODEL (EFAM)

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I. INTRODUCTION

1. Purpose. This annex presents the results of a system analysis performed by ESC to support the development of the Engineer Functional Area Model (EFAM).

2. Scope. The analysis described in this annex:

- a. Outlines the system to be modeled and its environment.
- b. Defines the model's specifications.
- c. Presents an outline development plan of desired program milestones, estimated resource requirements, and coordination requirements.

3. Method. In the field of software engineering, the software life cycle begins with the development of the system's specifications and proceeds through its design, implementation, and ends with the requirements to maintain the model until revision, when the cycle begins again.¹ The purpose of ESC's analysis was to complete the first phase of this cycle: development of the system's specifications. **Figure D-1** outlines the three-step methodology ESC followed to build a set of functional requirements for EFAM.

a. **System outline**. ESC worked closely with the United States Army Engineer School (USAES) to decide what the model will do, define how the model would be used, and what information will be output by the model. After the basic direction of the model was agreed upon, ESC worked with the USAES to evaluate proposals of alternative model configurations -- eventually deciding on a design approach for EFAM.

b. **Requirements specifications**. Using the EFAM design approach as a starting point, specifications were developed for the model's battlefield representation, engineer command and control representation, engineer task representation, and data inputs.

(1) The requirements specifications were based on a literature search of regulations, policy documents, studies, memoranda, and similar material pertaining to Army Model Improvement Program (AMIP) and force-on-force simulations. Interviews were also conducted with key personnel of: USAES; Department of the Army (DA); TRADOC Analysis Command, White Sands

¹Wiener, Richard, and Richard Sincovec, *Software Engineering With Modula-2 and ADA* (John Wiley and Sons, 1984)

EFAM METHODOLOGY

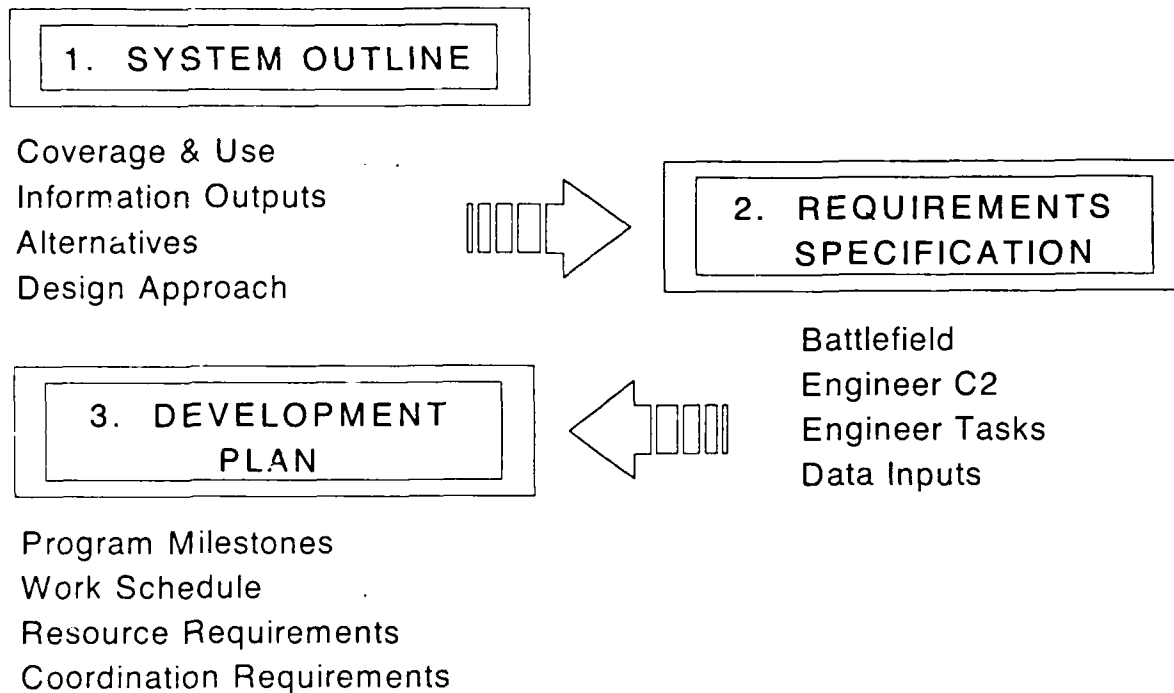


Figure D-1

(TRAC-WSMR); TRADOC Analysis Command, Fort Leavenworth (TRAC-FLVN); and US Army Corps of Engineers (USACE) personnel. Annex H presents a complete bibliography of sources cited or referenced while this section was being prepared.

(2) A separate ESC analysis, described in Annex F, set additional criteria for EFAM's engineer task representation.

c. **Development plan.** A three-year development plan was established for the EFAM using time/budget resource-use estimates provided by experienced model developers.

4. **Limits.** The requirements specifications in section III state what EFAM will eventually do, but do not describe how it will do it. Final decisions about how EFAM's supporting software will be configured will be left to the software developer, who will perform the detail design work and eventually implement the model.

5. Background. The original requirements for the development of functional area models (FAMs) were established in 1981 by Army Regulation (AR) 5-11, *Army Model Improvement Program (AMIP)*. Additional emphasis was placed on the program in 1985 when General Thurman, then Army Vice Chief of Staff, asked for an assessment of AMIP's FAM program:

As AMIP continues to develop the force-on-force models, I want to increase the emphasis on functional area models. The FAMs, if we can establish their credibility, have the potential payoff of identifying and substantiating the 'eaches' in our procurement programs.²

a. In response to General Thurman's tasking, the Training and Doctrine Command (TRADOC) schools and centers met at Fort Leavenworth in October 1985 to define the combat modeling requirements for six functional areas: maneuver (infantry, armor, aviation, and engineer), fire support, intelligence and electronic warfare (IEW), combat service support (CSS), air defense, and tactical command and control. The meeting established a TRADOC goal to develop, by November 1987, operational prototypes for each FAM. Unfortunately, 1986 saw little movement toward that goal.

b. In October 1986, the Army Models Committee (AMC) tasked the AMMO to establish an advisory group to assess the needs, technical feasibility, and capability of the analytical community to develop a set of high resolution FAMs. These models would be directly or indirectly tied to a corps level combined arms combat model. Membership included representatives of Army Materiel Systems Analysis Agency (AMSAA), Concepts Analysis Agency (CAA), TRADOC Analysis Command (TRAC), and AMMO. At its first meeting on 8-9 December 1986, the group evaluated, among other issues, the relationship between VIC and the combat modeling requirements of five functional areas: air defense, engineer, fire support, intelligence/electronic warfare, and combat service support. Several recommendations to the AMC Executive Group came out of that meeting:

(1) VIC appears to be a reasonable, balanced, and adequate representation of corps-level combat.

²AMIP briefing notes, MAJ Bruce Goetz, Army Model Improvement Program Management Office (AMMO), Fort Leavenworth, Kansas, January 1987.

(2) VIC is not detailed enough to meet the needs of every functional area.

(3) VIC should be used as the combat context generator for functional area analysis.

(4) FAM output should be used by the VIC design teams to determine if the reference version of VIC, which contains a more abstract representation of a function, provides the fidelity needed by the Army Study Program.

(5) Functional area models should not be forcibly embedded into the reference version of VIC.

(6) The analytical community should design and develop valid FAMs and ensure that VIC's representation of each functional area is consistent with the FAMs.

c. At subsequent meetings (10-11 March 1987, 13-17 April 1987, and 6 October 1987), the advisory group continued to review the needs and capabilities of the functional areas. ESC's participation at each of these meetings has been instrumental in obtaining the advisory group's recognition of the need for an EFAM and AMMO funding (\$200,000) for initial model development efforts. The following sections of this Annex present the EFAM program in greater detail than previously presented to the FAM advisory group.

II. OUTLINE OF THE SYSTEM AND ITS ENVIRONMENT

6. Coverage and Use.

a. Each proposal for improving the Army's equipment, organization, or training must be analyzed in detail to demonstrate the cost and operational effectiveness of the proposed change. Those organizations or systems with the greatest perceived pay-off are chosen. Combat engineer systems often do not make the initial cut. Some of the reasons are:

(1) The Army land combat models do not adequately demonstrate the contribution of engineer systems to the combined arms battle.

(2) Engineer-sponsored studies are typically not high on the TRADOC list of priority studies. Therefore, they are often performed without modeling support from the TRAC.

(3) The USAES has access to several models, but none that are both adequate to address engineer-specific questions and provide credible results in the eyes of the Army's analytical community.

b. The EFAM will correct these deficiencies by providing engineer modelers with an appropriate, analytically acceptable and approved corps-level (i.e., engineer brigade-level) model. In general, the types of analyses which this model will be used to address are:

(1) Engineer force structure or design questions.

(2) Engineer logistics questions.

(3) Contribution of engineers to the combined arms conflict.

c. In performing these analyses, the model is likely to be used as both a capabilities and a requirements model.

(1) Capabilities mode. At the outset of a conflict, a finite set of resources (equipment, personnel, or logistics) is available to complete the required work. In this mode, one can analyze how much the engineer force can accomplish and contribute with constrained resources.

(2) Requirements mode. In the requirements mode, resources are not constrained or limited. The intent of this type of analysis is to determine the combined arms demand for engineer work, and the resources required to meet that demand.

7. Information Outputs. To accomplish the goals of an EFAM, the following information must be obtained from the model:

a. Task frequency information.

(1) Chronology of engineer tasks to include time, task type, location, emplacing unit, maneuver unit supported, technique employed, and task duration.

(2) Number of tasks by type over time.

b. Engineer performance/efficiency information.

(1) Engineer system profile (percentage of time working, traveling, spent idle, and other).

(2) Engineer equipment and personnel attrition profiles.

(3) Number, type, and percentage of requested tasks which were not started.

(4) Number and percentage of started tasks, by type, which were terminated before being finished.

(5) Record of logistic item shortages and stockage levels.

(6) Flow of repaired and reconstituted engineer equipment.

c. Engineer contribution/effects information.

(1) Forward line of troops movement data.

(2) Killer/victim scoreboard (including mines).

(3) Battle duration.

(4) Percentage of engagements supported by obstacles.

(5) Number of obstacles encountered and delay on each.

(6) Average delay by obstacle type.

(7) Percent of engagements supported by survivability tasks (protective positions).

(8) Average reduction in attrition due to survivability tasks (protective positions).

(9) Delay and attrition for river crossing operations.

(10) Length of downtime for damaged facilities (airfields, major supply routes, ammunition storage, hospitals, etc.).

(11) Flow of resources through logistics facilities.

8. Broad Alternative Solutions. Any alternative for providing the information required from the EFAM must supply two items: a realistic corps-level combat generator (battlefield representation with combined arms

activities), and a detailed engineer command and control program (task execution, unit/force allocations, and equipment/personnel attrition). This section will discuss several alternatives for developing an EFAM.

a. **Alternative 1--independent development.** Both components of the EFAM would be developed independent of the AMIP models.

(1) Advantages. The EFAM could be tailored to the specific requirements of the engineer community and designed against the ability of the USAES to operate and maintain the model.

(2) Disadvantages. The development of a corps-level combat generator is not a simple task. The development time would be long and the resource requirements high. In addition, it would be difficult to obtain credibility for the model if it was developed outside the AMIP process. Finally, independent development is contrary to the Army's goal to stem proliferation and to standardize models.

b. **Alternative 2--dependent but stand-alone.** This approach would use an existing AMIP model as the basis for the combat generator. Since VIC is now the corps/division model of choice (Corps/Division Evaluation Model [CORDIVEM] has been discontinued and Conflict Model [CONMOD] is still under development), the combat generator would be based on the VIC model. The engineer command and control programs within VIC would be enhanced to the appropriate resolution for an EFAM, VIC's terrain representation and movement algorithms would be improved, and this new version of VIC (now called the EFAM) would be a complete, stand-alone model to be used by the USAES.

(1) Advantages. Since VIC is already a standard production model, the development time for the EFAM would be reduced. The USAES could perform their analyses using TRADOC scenarios and TRAC data bases already developed for other VIC studies.

(2) Disadvantages. Since VIC is resource-intensive, an EFAM based on VIC will be difficult for the USAES to operate and maintain. Since a high-resolution engineer representation in EFAM would probably produce results that are "different" from VIC, it may be difficult to establish credibility for the model.

c. **Alternative 3--modular plug-in.** The VIC model would contain a balanced representation of the engineer functions, but at a modest resolution. The EFAM would consist of a high-resolution module for engineer representation

that could be plugged into VIC and replace its organic engineer representation.

(1) Advantages. This is an eloquent approach, providing the capability for the VIC model to switch between low- or high-resolution engineer play. This EFAM could support the analysis needs of the entire analytical community, not just the USAES. Finally, this approach would produce a model with the highest level of credibility, since this is the approach that is the most closely tied to VIC.

(2) Disadvantages. The primary disadvantage of the plug-in approach is that it may not be possible to accurately play engineers without modifying the current representation of the battlefield in VIC. The concept should work quite well for a function like logistics, where items can be accounted for, requested, supplied, and consumed at various levels of resolution. The engineers, on the other hand, do not simply operate within the battlefield-- they *modify* it. Thus, engineers are vital to defining the mobility, countermobility, and survivability of maneuver forces. Therefore, the ability to represent engineer task and force effectiveness at a high level of resolution depends on some primary characteristics of the combat generator, including terrain resolution and cross-country movement algorithms. Since the current reference version of VIC is not "plug" compatible with a high-resolution engineer module, the success of the EFAM would rest on the VIC community's willingness to incorporate the necessary overhead into VIC. Finally, as in Alternative 2, the resulting model will be resource-intensive and difficult for the USAES to operate and maintain.

9. General Design Approach. At this time, ESC recommends alternative 2. Attempting to accommodate both low- and high-resolution engineer play in VIC will overly complicate the VIC model. By making the EFAM a special purpose, stand-alone model, both models, VIC and EFAM, can be streamlined to better serve their intended functions. On the other hand, ESC recognizes the merits of Alternative 3 and will not altogether abandon this approach.

a. Every effort will be made to maintain compatibility between the reference VIC model and the EFAM. The two models will be stand-alone, but logically linked. Figure D-2 shows the following general steps in this process (detailed requirement specifications are discussed in Section III):

EFAM DESIGN APPROACH

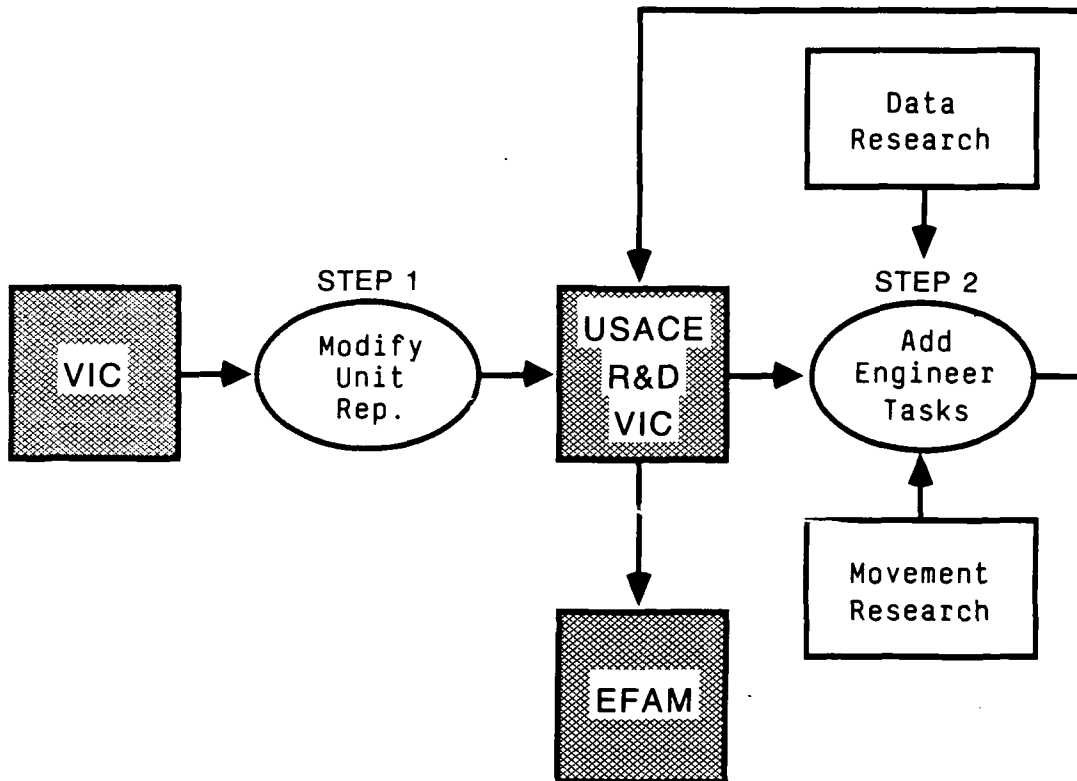


Figure D-2

(1) Step 1. Replace the current representation of engineer units in VIC (see Annex B) with a more flexible modeling arrangement. This will improve the realism of the engineer tasks currently played in the model and permit the inclusion of additional engineer tasks. This modified version of VIC is referred to as the USACE R&D VIC.

(2) Step 2. Systematically implement additional engineer tasks in the USACE R&D VIC. Model modifications will be phased; starting first with those modifications desired by the engineer community for the reference

version of VIC, and second with EFAM unique requirements. Concurrent with this modeling effort, the following two research programs will be underway: the identification, collection, and validation of data requirements; and the design, development, and testing of improved unit movement and terrain representation. Both of these efforts are needed to ensure that engineer task effects are realistically modeled.

b. Step 2 modifications will be performed in phases. This iterative approach will periodically produce a new version of the USACE R&D VIC which will serve as a prototype EFAM. Every effort will be made to produce an EFAM that satisfies the requirements of the engineer community without radically departing from the VIC model.

III. REQUIREMENTS SPECIFICATION

10. Battlefield Representation.

a. **Terrain resolution.** Since engineers emplace and remove natural or manmade obstacles, the battlefield terrain must be specified with sufficient resolution to identify their location and character. The terrain must also be sufficiently detailed to identify river crossing sites, cross-country mobility, and locations for protective positions. LOC networks must also be specified so the model can generate the appropriate number of point obstacles (road craters and blown bridges). Finally, since urban areas are a part of the battlefield, they must be characterized in detail (see Annex E for the digitized terrain requirements to support VIC).

b. **Dynamic movement.** Maneuver units of both forces must be able to dynamically alter their routes to respond to the changes imposed by engineer obstacles.

c. **Threat.** The threat forces must be realistically portrayed in terms of capabilities, vulnerability, task times, and travel rates.

11. Engineer Command and Control Representation.

a. **Resolution.** Engineer equipment must be identified at the individual item level, with different types of equipment items represented. Personnel must be identified to the engineer team level (smaller than platoon size). The different types of engineer teams (such as bridging, obstacle breaching, or trail cutting teams) must be represented.

b. **Force structure.** The model must portray the traditional engineer hierarchical structure of teams, squads, platoons, companies, and battalions. It must also monitor on-hand assets and modify or redistribute assets to meet the mission needs. Realistic command relationships must exist (direct support, general support, etc.) for nondivisional combat engineer units, as well as for engineer heavy battalions and combat support equipment companies. Since many of the studies supported by the EFAM will concern future time frames, the model must be easily adaptable to changing force structures, unit designs, and materiel.

c. **Resource allocation.** The model must manage all engineer items of equipment and allocate personnel and equipment to tasks. When an engineer task is requested, the required engineer assets travel from their current

location to the worksite, and perform the task. To properly manage this, a priority scheme and queue must be established for engineer tasks.

d. **Combat Service Support (CSS).** Engineers must be tied into the logistics system. Class III, IV, and V materiel must be managed, transported, and allocated to engineers. Engineer equipment and personnel must also be tied to the support structure to ensure that casualties are evacuated and replaced, and that damaged equipment is evacuated, repaired, and reissued.

e. **Attrition.** Engineer equipment and personnel must suffer attrition from both direct and indirect fires. The model must assure that this attrition is commensurate with the specific entity's vulnerability and can occur during any phase of work or movement.

f. **Engineer activities by non-engineers.** Not all engineer tasks on the battlefield are performed by engineer personnel and equipment. Management of these activities and the availability of resources to perform them must be handled within the resources and priorities of other proponent branches. For example, EFAM should consider the use of mines and demolition by field artillery, aviation, air force, armor, and infantry.

12. **Engineer Task Representation.** Annex F identifies those engineer tasks which should be represented in combat simulations at each level of the AMIP hierarchy. However, the Engineer Model Improvement Program (EMIP) is somewhat unique, since it is a mid-resolution (corps-level) simulation with high-resolution (team-level) engineer representation. The following paragraphs complement the discussion of engineer tasks in Annex F, and identify the engineer tasks to be modeled in the EFAM.

a. **Mobility tasks.** Figure D-3 lists the four major categories of mobility tasks that must be represented in the EFAM.

(1) Engineers must have alternative courses of action for overcoming each type of obstacle encountered. These alternatives should encompass breaching techniques -- with or without engineer support -- plus a by-pass option.

(2) The orchestration or action of the maneuver units during counterobstacle operations must be consistent with the breaching technique being employed.

(3) Each type of obstacle must have individual characteristics (width, depth, effects on maneuver elements).

EFAM MOBILITY TASKS

Breach obstacles in the assault

- Minefields
- Antitank ditches (ATD)
- Road craters
- Dry gaps
- Complex obstacles

Conduct river crossing operations in the assault

- Armored vehicle launched bridge (AVLB)
- Rafting
- Fording
- Access
- Egress

Prepare and maintain pioneer trails

Remove nuclear rubble

Repair and maintain forward airlanding facilities

Figure D-3

(4) The maneuver forces cannot have perfect knowledge of the obstacle boundaries or locations. Knowledge of an obstacle is only obtainable through intelligence or encounter.

(5) The model must play the following obstacle breaching techniques:

(a) Forcing through: Forcing through is the crossing of an obstacle without the benefit of countermine or counterobstacle equipment. Visual observation is the only means dismounted troops or vehicle drivers use to avoid obstacles or mines. Negotiating the obstacle in this manner involves the highest risk and is attempted only when it is imperative to maintain the momentum of the attack or when no other means is available.

(b) Hasty breach: In the hasty breach, the attacking force maintains the momentum of the attack by attempting to breach "in stride" as it encounters the minefield or obstacle. A hasty breach is conducted by maneuver units with immediately available assets and often without combat engineer participation.

(c) Deliberate breach: The deliberate breach is conducted when it is not possible to take the minefield or obstacle in stride or after a hasty breach has failed. Combat engineer support is essential. A deliberate breach will normally be conducted after momentum has been lost. More time is required for reconnaissance, planning, and build-up of necessary resources than is possible for a hasty breach.

(6) Engineers must be able to create and maintain combat roads and trails as the simulation progresses. The construction time for these tasks will depend on the equipment available and the terrain conditions being encountered. The mobility rates along these roads will be commensurate with the quality of road constructed.

b. Countermobility tasks. Figure D-4 lists the countermobility tasks that must be represented in the EFAM.

EFAM COUNTERMOBILITY TASKS

Install linear obstacles

- Conventional minefields
- Scatterable minefields
- Antitank ditches
- Other linear obstacles
 - Antitank wall
 - Concertina and barbed wire
 - Flooding
 - Fire
- Complex obstacles

Install point obstacles

- Road craters
- Bridge demolition

Figure D-4

(1) All types of minefields must be represented with variable size and density. The emplacement time, size, and density must be consistent with the delivery device. Types of scatterable mines should include the ground emplaced mine scattering system (GEMSS), VOLCANO, modular pack mine

system (MOPMS), area denial artillery munition (ADAM)/remote anti-armor mine system (RAAMS), wide angle mine (WAM), and GATOR/M56.

(2) Each individual mine type must have realistic probabilities of kill, reliabilities, and self-destruct times.

(3) Obstacles, like minefields, must be variable in size. The emplacement time and obstacle size must be consistent with the emplacement device. Various techniques can be used for a single type of obstacle. A tank ditch is a prime example, and any of these techniques can create it: armored combat earthmover (ACE), dozer, scooploader, or explosives.

(4) Each type of obstacle must have the option of being featured with, or surrounded by, a minefield.

c. **Survivability tasks.** Figure D-5 lists the survivability tasks that must be represented in the EFAM.

EFAM SURVIVABILITY TASKS

Prepare fighting positions for direct fire systems
Prepare positions for indirect fire and other systems
Camouflage and deception

Figure D-5

(1) Engineers must be able to construct fighting positions for tactical vehicles and weapons systems. Protective emplacements for artillery, air defense units, and logistics concentrations must be an option, as well as the hardening of key command and control facilities.

(2) When maneuver units halt, engineers must build and improve as many protective positions as possible. When units stop for breaching operations, for example, engineers should provide protective positions for antitank and indirect fire weapons and for critical supplies such as ammunition.

(3) Fighting positions must be represented by three levels: half defilade, firing defilade, and full defilade. Each level should reduce the exposed target area with a resulting reduction in probability of kill.

(4) Through the employment of engineers, or other camouflage efforts, the level of acquisition should be reduced for vehicles or personnel who have employed camouflage.

d. Sustainment engineering tasks. Figure D-6 lists the sustainment engineering tasks that must be represented in the EFAM.

EFAM SUSTAINMENT ENGINEERING TASKS

Improve river crossing sites for follow-on forces

Fixed bridging

Float bridging

Improve assault breaches for follow-on forces

Clear minefields

Widen lanes

Prepare and maintain forward airlanding facilities

Maintain main supply routes (MSR)

Roads

Railroads

Bridges

Prepare and maintain sites for CS and CSS units

Rehabilitate and maintain rear area facilities

Repair Airfield Damage

Construct and repair port and waterfront facilities

Figure D-6

(1) Each facility (roads, railroads, petroleum, oils, lubricants [POL] sites, hospitals, etc.) must be deteriorated with usage, which reduces the flow of assets through that facility. Engineers can expend maintenance effort to keep these facilities operating at full capacity.

(2) All facilities must be capable of receiving war damage, which also precludes or limits their use. Engineers can then be used to repair these facilities.

13. Data Inputs. EFAM's high resolution play of engineer force capabilities and engineer task effectiveness will require an intensive data development effort. Since the architectural design is based on the VIC model, the logic and structure of the data base has been predefined, but much of the engineering-related data within VIC will have to be replaced or supplemented. Figure D-7 lists the five major categories of data that are vital for EFAM operation.

EFAM DATA REQUIREMENTS

1. **Engineer task representation**
 - Task priority
 - Techniques available
 - Resource requirements
 - Base preparation time
 - Engineer team movement rates
 - Task completion times
 2. **Weapon systems vulnerability**
 - Exposed
 - Firing defilade
 - Half defilade
 - Full defilade
 3. **Engineer systems vulnerability**
 4. **Minefield systems effectiveness (by density and type)**
 - Attrition factors
 - Self-destruct times
 5. **Battlefield representation**
 - Terrain
 - Cross-country mobility
 - Lines of Communication (LOC) capacities and degradation factors
 - Depots
 - Roads
 - Railroads
 - Airfields
 - Ports
-

Figure D-7

IV. DEVELOPMENT PLAN

14. Program Milestones and Work Schedule. Using VIC as the base model for the EFAM will fix both the logical and physical design of the model, as well as structure of the data base. The developmental program, therefore, should be viewed as a model enhancement program with an abbreviated life cycle. Most of the software developer's effort will be spent on modifying VIC to accommodate the specifications cited in section III. Those modifications that are also recommended for future reference versions of the VIC model (see Annex B) are scheduled first. All modifications should take no longer than 3 years, and the operational model should be delivered to USAES in FY91. Prototypes will be available on a one-year cycle. Figure D-8 shows the program milestones and work schedule.

EFAM PROGRAM SCHEDULE

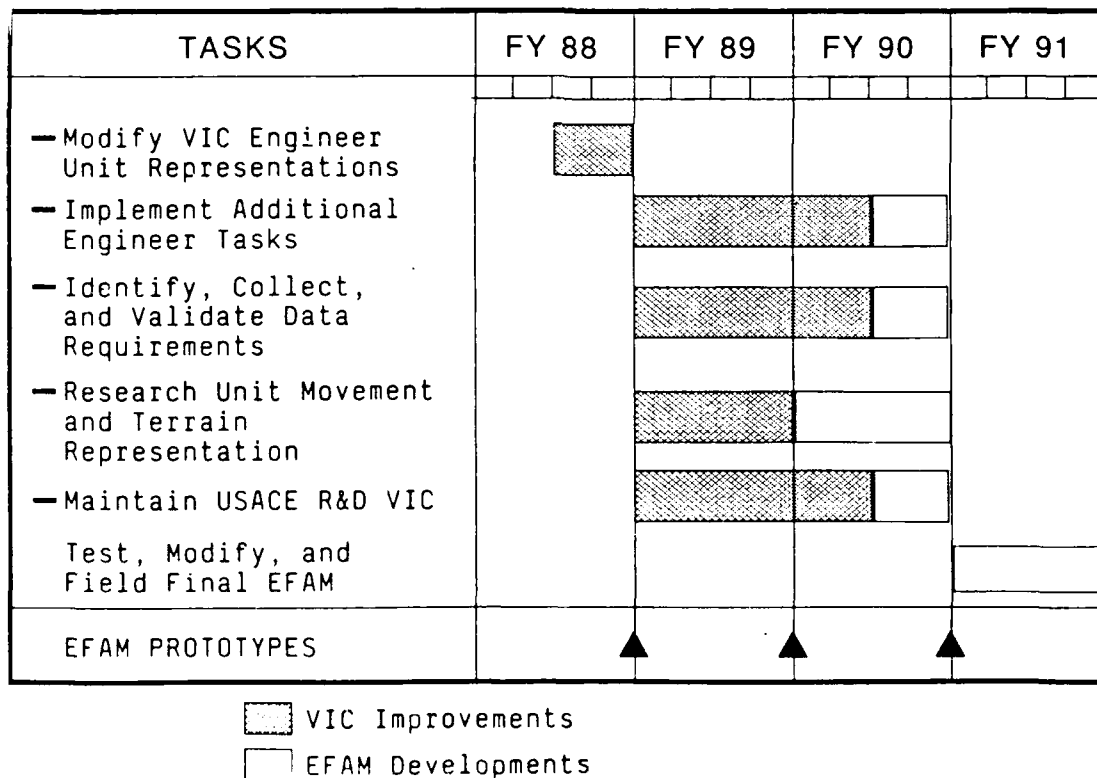


Figure D-8

15. Resource Requirements. The majority of the EFAM program schedule can be accomplished through a cooperative effort by Construction Engineering Research Laboratory (CERL) and Waterways Experiment Station (WES). There are two possible exceptions: digitized terrain requirements should be met by Engineer Topographic Laboratories (ETL), and data requirements by a contractor. ESC estimates that the total EFAM development effort will require 16 professional staff years, and cost slightly less than \$2 million (\$120,000 per professional staff year). Since the VIC program directly benefits from approximately 75 percent of this effort (as shown in Figure D-8), the net cost of the EFAM will be considerably less. The phasing of the professional staff year estimates is shown in Figure D-9.

EFAM RESOURCE REQUIREMENTS

TASKS	FY 88	FY 89	FY 90	FY 91
— Modify VIC Engineer Unit Representations	1			
— Implement Additional Engineer Tasks		2	2	
— Identify, Collect, and Validate Data Requirements		2	1	
— Research Unit Movement and Terrain Representation		2	1	
— Maintain USACE R&D VIC		2	2	
— Test, Modify, and Field Final EFAM				1
PROFESSIONAL STAFF YEARS	1	8	6	1

 CERL
  WES
  OTHER

Figure D-9

16. Coordination Requirements. As the EFAM program monitor, ESC will establish and maintain the necessary coordination and support agreements. The primary mechanism for this coordination will be an EFAM Advisory Group.

Membership will be solicited from the following key organizations:

- a. USAES: model proponent and user representative
- b. AMMO/FAM advisory group: funding support
- c. TRAC: proponent of VIC
- d. Directorate of Research and Development, USACE: program development for USACE laboratories
- e. ETL: digitized terrain requirements
- f. AMSAA: proponent for item systems data
- g. OACE: technical monitor

ANNEX E

DIGITAL TERRAIN DATA IN SUPPORT OF LAND COMBAT MODELS

ANNEX E

DIGITAL TERRAIN DATA IN SUPPORT OF LAND COMBAT MODELS

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I. INTRODUCTION

1. Purpose. This annex identifies requirements for digital terrain data (DTD) in combat simulations at each level in the hierarchy of Army models. Three specific models (CASTFOREM, VIC, and FORCEM) were examined to determine how they use terrain data and to assess the availability of DTD at the different levels of resolution required by these models.

2. Scope. This analysis evaluates:

a. The status of DTD production in the Army and at the Defense Mapping Agency (DMA) -- in terms of database content and geographic coverage.

b. The DTD requirements of high-, medium-, and low-resolution Army models (as represented by CASTFOREM, VIC, and FORCEM) -- also in terms of database content and geographic coverage.

3. Background. Advances in data collection and processing technology are changing the way the mapping, charting, and geodetic (MC&G) community collects and represents terrain information. Labor-intensive manual mapping procedures are giving way to a variety of automated and semi-automated mapping methods that electronically digitize topographic features and terrain information. These automated capabilities will greatly enhance the ability to store, manipulate, update, and display topographic products. The transformation is occurring at all levels of the Department of Defense, from the mapping experts at DMA to Army topographic field units. As a result, MC&G organizations, methods, and equipment are now being prepared to operate in the digital environment of the future. These changes will affect the way combat simulation models accept and interpret information about the physical battlefield environment.

a. **DMA responsibilities**. DMA produces, revises, and distributes standard MC&G products throughout the DOD community. To keep pace with the demand for digital products, DMA is changing its mapping methods and equipment. DMA's Systems Center is coordinating the design and development of the Mark 90 modernization program, which is a new, computer-oriented, highly automated production system. The Mark 90 system is designed to produce 28 or more standard products.¹ A new tactical terrain data (TTD) set that is currently

¹Tactical Terrain Data Prototype (DMA, 9 October 1987).

under development will be added to the list of Mark 90 products in the near future. The complete set of Mark 90 standard products will meet a significant portion of the DOD community's digital terrain requirements. However, DMA will not begin TTD production until the Mark 90 system reaches its initial operational capability in 1992 or later. In the interim (1988-1992), the Army's requirements for DTD must be met with current standard products or interim terrain data (ITD) produced to meet the most urgent needs. Among the standard digital terrain products DMA can now produce are:

- (1) Digital terrain elevation data (DTED)
- (2) Digital feature analysis data (DFAD)
- (3) Counter-Artillery, Counter-Battery Locating System (FIREFINDER)
- (4) Vertical Obstruction Data (VOD)
- (5) Terrain Contour Matching (TERCOM)

b. **Army responsibilities.** The Army is also changing to take advantage of the capabilities of the new digital topographic world. The Engineer Topographic Laboratories (ETL) are developing the digital topographic support system (DTSS) that will enable US Army topographic field units to operate in a digital production mode. Two reports prepared by the ETL outline Army digital terrain requirements for weapon systems, tactical support systems, training systems, and modeling.² Initially, DMA indicated that requirements not met by the current standard digital products (DTED, DFAD) would not be satisfied until the Mark 90 system became operational and started producing TTD. Thus, the Army is faced with a near-term (1988-1992) shortfall in the availability of new digital terrain data. The Army topographic community is concerned that TTD production by Mark 90 in 1992 may be optimistic -- and when the Mark 90 system comes on line, it will take time to develop the data bases and build the area coverage needed to satisfy all mid-term (1993-2002) Army DTD requirements.³ However, ETL's Concepts and Analysis

²Herrmann, Richard A., et al., *Army Digital Topographic Data Requirements*, Report ETL-GSL-4 (ETL, August 84) and Regis J. Orsinger, et al., *Army Tactical Digital Terrain Data Requirements*, Report ETL-SR-1 (ETL, July 1987).

³Personal conversation between Mr. Richard L. Taylor of ESC, and LTC John Olesak, Office of the Deputy Chief of Staff for Intelligence (ODCSINT), November 20, 1987 and the ETL Command Briefing presented to ESC personnel by COL Alan Laubscher, November 30, 1987.

Division (CAD) is committed to ensuring that the Army's near-term requirements for a tactical-level digital terrain analysis product are fulfilled by an acceptable means. To this end, both ETL and the Office of the Deputy Chief of Staff for Intelligence (ODCSINT) have represented the Army in discussions with the Defense Mapping Agency (DMA) to provide an ITD product to adequately and expediently service the Army's near-term (1988-1993+) tactical and analysis community requirements for digital terrain data sets (before TTD is available in volume). DMA's recent decision to support the DTSS with a volume of ITD required for operational deployment has been underscored by their commitment to develop a product specification for ITD by 31 August 1988 and deliver a prototype data set to the Army by the end of 1988. ITD, to be acceptable by the Army must be easily usable, cost effective, and adaptable to either existing or near-term fieldable Army tactical and non-tactical systems/programs with respect to their operating systems and specific applications. ITD must also be co-producible by the Army and private industry. Finally, ITD should be economically translatable to the future DMA TTD.

4. Limits. This analysis focuses on the MC&G community's ability to meet the DTD needs of existing models -- it does not attempt to specify standard DTD formats, structures, or transformations. DTD standards should be determined by a thorough analysis and evaluation of the digital terrain requirements of weapon systems and tactical support systems. Models should take advantage of the available DTD products, but they should not preempt the requirements of systems in the field. This analysis did consider the results of a 1984 ETL study which consolidated the Army's DTD requirements (to include the Army modeling community).⁴ These specifications form the basis of DMA's TTD specifications, as well as the Army's special terrain data (STD) specifications. The STD specifications are designed to meet Army high-resolution DTD requirements not met by TTD. Together, TTD and STD will serve as the Army's standard DTD sets for the future.

5. Approach. This analysis began with a review of Department of the Army (DA) Pamphlet 25-30 to identify technical manuals, field manuals,

⁴Army Digital Topographic Data Requirements, Volume IV: US Army Specifications for DTD Requirements, Report ETL-GSL-4 (ETL, August 1984).

regulations or other publications relating to the Army's use of DTD. Next, interviews were conducted with the key personnel who produce and use DTD, as well as those who prepare reports relating to DTD. Among those interviewed were representatives of various DOD and Army staff elements, including: DMA, ODCSINT, and the Assistant Chief of Engineers (ACE). Information pertinent to the state of DTD production was also obtained from ETL, the Waterways Experiment Station (WES), the US Army TRADOC Analysis Command at White Sands Missile Range (TRAC-WSMR), and the US Army Concepts Analysis Agency (CAA).

II. STATUS OF DTD DATA AND PRODUCTION

6. DTD Production. The uses of DTD, the technology needed to generate DTD, and the organizations tasked to produce DTD have all evolved rapidly over the past 10 years. The production of standard military DTD is the mission of DMA. ETL has the responsibility of coordinating Army requirements with DMA. ETL also has responsibility for managing research, development, and production of Army DTD requirements that are not met by DMA. The US Army Corps of Engineers Research and Development (USACE R&D) community, Army field units, and private contractors are also involved in producing DTD to meet special requirements. Because the different DTD products developed by these organizations have evolved over time to meet specific requirements, they are not always compatible. The different DTD vary in content (elevation, vegetation, lines of communication, etc.), format (raster or vector), resolution (raster grid size or vector data density), data structure (data base layout), accuracy (location error), geographic coverage (Europe, Central America, etc.), and means of data base generation (fully automated or manually entered). Figure E-1 gives a summary of the features of some key DTD data sets. The long range goal of the MC&G community is to standardize DTD requirements. However, until the DMA Mark 90 program becomes operational, the modeling community must make the best use of all existing sources of DTD. Therefore, this analysis does not distinguish between original sources of digital terrain production and sources that acquire digitized elevation data from another DTD source and add additional terrain feature data. It was assumed that DTD, no matter where or how produced, is available to support model users.

7. DMA. Two offices at DMA are primarily responsible for producing DTD: the Hydrographic/Topographic Center and the Aerospace Center. Two significant standard DTD products prepared in these centers are considered essential to Army modelers: digital terrain elevation data (DTED), and digital feature analysis data (DFAD). DTD for the FIREFINDER system is also produced at DMA and, where coverage is available, it should be considered for model use. Since the location of DTD coverage for FIREFINDER could reveal potential deployment locations of FIREFINDER systems, this information is classified and is not included in this report. DMA has also produced limited

A SUMMARY OF MAJOR DTD DATA SET FEATURES

DATA SET	STATUS	FEATURE DENSITY	TERRAIN FEATURES
DTED (level 1)	operational	3 arc-sec (100 m)	elevation
DTED (level 2)	limited coverage	1 arc-sec (30 m)	elevation
DFAD (level 1, edition 1)	operational	1:250,000 map equivalent	vegetation, surface material
DFAD (level 1, edition 2)	limited coverage	1:250,000 map equivalent	vegetation, surface material, LOCs
DFAD (level 1-C)	limited coverage (cartographic sources)	1:250,000 map equivalent	vegetation, surface material, LOCs
DFAD (level 2, edition 1)	limited coverage	1:50,000 map equivalent	vegetation, surface material
DFAD (level 2, edition 2)	limited coverage	1:50,000 map equivalent	vegetation, surface material, LOCs
ARTBASS	operational (non-standard product)	12.5-25 m	elevation, vegetation, CCM, rivers, roads, railroads, and bridges
Mobility Database (WES)	operational (non-standard product)	25-100 m	elevation, tree height, CCM, roads, vehicle speeds
ALBE	limited coverage (tech base demonstration)	100m	elevation, vegetation, slope, surface material, obstacle height, canopy closure, roads, rivers, railroads, bridges, tunnels, dams, airfields and meteorology
TTD	developmental	1:50,000 map equivalent	elevation, vegetation, slope, surface material, obstacles, urban areas, rivers, roads, railroads, bridges, and tunnels

Figure E-1

sets of non-standard DTD. The initial sets of DTD for the Army Training Battle Simulation System (ARTBASS) were produced by DMA (ETL is now coordinating the production of additional DTD for ARTBASS through contract). DMA also produced the non-standard DTD set called ITD. In one form or another, these products supply most of the DMA-produced DTD used by Army combat simulation models. See Appendix E-1 for displays of the geographic coverage of these products. DMA also produces two hard copy terrain data sets that are primary sources of terrain feature data for encoding in DTD products -- tactical terrain analysis data base (TTADB) is a set of feature overlays at 1:50,000 scale, and planning terrain analysis data base (PTADB) is a set of overlays at 1:250,000 scale.

8. USACE R&D Centers. Three USACE R&D laboratories are producing or updating DTD for Army use. ETL has the lead for DTD, but WES and the Construction Engineering Research Laboratory (CERL) both produce DTD products under reimbursable agreements to meet certain Army requirements.

a. ETL. Four non-standard DTD sources designed to meet unique Army requirements are managed by ETL: two are the responsibility of the Geographic Sciences Laboratory (GSL) and two are the responsibility of the Terrain Analysis Center (TAC).

(1) GSL oversees the terrain analysis work station (TAWS) project, the DTSS, and the air land battle environment (ALBE) test beds. These GSL systems are based on the Analytical Mapping System (AMS)/Multiple Overlay and Statistical System (MOSS) geographic information system (GIS). A GIS is a system for encoding, processing, manipulating, and generating spatial data -- in this case, terrain information. Each system can produce DTD but only does so for its own use. Both systems have been using hard copy TTADBs as source materials.

(2) TAC is now installing a GIS with the intent of processing worldwide water resources data in digital format. This will give TAC's GIS the ability to expand to include multi-theme DTD. TAC is also the Army's center for transforming DMA-produced DTED from tape to computer disk and video cassette for use on Microfix(T) systems. TAC produces hard copy ARTBASS data for Army users and manages contracts for the production of DTD for ARTBASS.

b. WES. The Mobility Systems Division of WES's Geotechnical Laboratory began developing digital mobility-terrain data bases in 1970 to

support the evaluation and validation of the Army Mobility Model (AMM). Continued development of mobility-terrain data bases, funded mainly by Training and Doctrine Command (TRADOC), has focused on providing realistic mobility input to the CARMONETTE and CASTFOREM wargaming models. The Modeling and Terrain Unit of the Mobility Systems Division produces DTD using a commercially developed GIS called ARC/INFO. ARC/INFO is a GIS system that can process and generate DTD from imagery, map sheets, and terrain overlays. WES uses many different terrain source materials, including TTADB.

c. **CERL.** Although CERL has not produced any DTD in support of Army combat simulation requirements, its Geographical Resources Analysis Support System (GRASS) can produce and process DTD data. This system is a GIS which supports CONUS installation planning and maintenance done by the USACE Engineering and Housing Support Center (EHSC). GRASS DTD has been produced for Fort Hood, and Fort Carson, and is now being generated for the Hoenfels Training area in West Germany.

d. **Summary.** Generically, the Army DTD is characterized by ARTBASS, TAWS, ALBE, and the WES data bases. While there are significant differences in these data sets in terms of their state of development and coverage, they each define terrain features as well as basic terrain elevation data. These feature data sets add information on vegetation, surface materials, surface drainage, transportation, and obstacles to more fully describe the terrain than can be done with elevation data alone. (Appendix E-3 lists the documents which give the specifications for these data sets.) These systems can accept digital terrain elevation data from other sources such as DTED or they can generate their own digital terrain elevation data through manual means. Additional terrain feature information for these DTD sets is manually input from hard copy sources such as the TTADB, standard 1:50,000 scale topographic line maps, and other collateral sources.

9. Army Engineer Field Units. Engineer Topographic units are developing the capability to produce and maintain DTD:

a. **29th Engineer Battalion (Topographic).** The 29th is the Pacific theater topographic support battalion. The battalion is now installing the first phase of its digital modernization plan -- a Microvax II system which will serve as the foundation for DTD production and processing. Later phases

will install various elements of the ALBE test bed system. By the end of 1988, the 29th will begin converting hard copy TTADB's to digital form.

b. **649th Engineer Battalion (Topographic).** The 649th is the European theater topographic support battalion. The battalion's limited DTD processing is now done by terrain teams using Microfix (T) systems. The 649th plans to eventually expand its DTD production capability to better support US Army Europe (USAREUR) terrain product needs.

c. **Other Topographic Units.** Similar conditions exist at the 30th Engineer Battalion (Topographic), which supports Third US Army missions, and the 1203d Engineer Battalion (Topographic), which is a National Guard unit.

d. The growing capability of field units to produce DTD must be coordinated by ETL to make sure the data sets produced are formatted properly and are available to users throughout the Army and, thus, avoid needless duplication of effort.

10. Contractors. Private firms have been a source of DTD in the past, and are expected to meet a portion of the Army's outstanding DTD requirements in the future. The BDM Corporation, the Jet Propulsion Laboratory (JPL), and various architectural and engineering firms have been suppliers of DTD in the past. Their DTD products are typically designed to support a specific model, analysis, or GIS data base. Once developed, the data can be applied to other uses as well. Since contractor-produced DTD is typically in non-standard format, other uses normally require reformatting.

III. DTD REQUIREMENTS FOR ARMY MODELS

11. DTD for The Hierarchy of Army Models. Every model has different requirements for terrain data based on its internal design, the types and sizes of forces it represents, the kinds of studies that use it, and the different geographic locations it must portray. The Army Model Improvement Program (AMIP) classifies models into a hierarchy based on their level of resolution. High resolution models require the greatest terrain detail but because they play smaller units (battalion and below), they operate on limited blocks of terrain. Medium resolution models need blocks of terrain large enough to maneuver division- and corps-size units and they sacrifice some terrain detail to get the area coverage they need. Low resolution models cover an entire theater of operation and, therefore, must be able to represent the geographic characteristics of theater lines of communication and strategically important terrain features like major avenues of approach. However, at the theater level it is not necessary to explicitly represent terrain in enough detail to support the play of tactical operations. ESC looked at the three AMIP automated simulations for the three levels in the hierarchy of Army models to better define the terrain requirements at each level of resolution. The three models (CASTFOREM, VIC, AND FORCEM) are discussed in detail in Annexes A, B, and C. Figure E-2 gives a summary of the terrain requirements of each model, and their use of DTD is summarized in the following paragraphs.

12. CASTFOREM Model Description. This evaluation of CASTFOREM's DTD requirements is based on a review of CASTFOREM documentation and interviews with the persons who maintain the CASTFOREM model.⁵ CASTFOREM has a modular structure. Events in the model trigger action in eight process modules: command and control, communications, engineer, movement, engagement, surveillance, system/environment, and combat service support (CSS). These

⁵CASTFOREM Executive Summary (TRAC-WSMR, Simulation Support Division III, 20 September 1986); *CASTFOREM Scenario Writer's Guide* (TRAC-WSMR, Simulation Support Division III, 29 June 1987); *CASTFOREM Cookbook.3* (TRAC-WSMR, Simulation Support Division III, 6 August 1985); and personal interview between Mr. Richard Taylor, ESC and Messrs. Freeberg, Mackey, Champion, and Denney of TRAC-WSMR on 16 November 1987.

A SUMMARY OF CASTFOREM, VIC, & FORCEM TERRAIN PARAMETERS

	CASTFOREM	VIC	FORCEM
STANDARD GRID CELL RESOLUTION	100 m	4 km	10 km
TYPICAL AREA OF OPERATION	12 x 20 km	150 x 150 km	irregular (theater dependent)
TERRAIN ATTRIBUTES MODELED *	elevation vegetation built-up areas canopy closure cross-country mobility (CCM) roads rivers obstacles	elevation vegetation built-up areas trafficability roads rivers obstacles	elevation movement capability in & out of cells LOC networks

* Since each model has its own categories and classifications, this is only a rough outline of the features covered by the models.

Figure E-2

modules are supported by various data types and data files. The data types and data files are used as reference points for the DTD requirements discussion.

a. **DTD Representation.** CASTFOREM represents terrain as square cells. The size of these cells is uniform within a terrain data set; however, the size of the cell can be changed to use different terrain data sets for different studies. Cells with 25-, 50-, and 100-meter sides have been used in the past. 100-meter grid cells are most often used because of the long run times involved with higher resolution grid cells, and the limited availability of higher resolution DTD to supply the model. There are nine terrain attributes for each cell that define roads, surface features, vegetation or built-up area heights, canopy closure, hydrography (rivers), cross-country movement (CCM) dry, CCM wet, elevation, and obstacles within that cell. One value is assigned for each of the terrain attributes within a cell. This means that the vegetation is of one uniform type, the elevation is of one height, and the CCM is of one value for the entire terrain cell. So far, all the terrain sets used by CASTFOREM have gotten input for these terrain attributes from the ARTBASS data base. Besides setting the grid cell size, the user sets the size of the area of operation (AO). AOs as small as 6 x 11 kilometers, and as large as 20 x 20 kilometers have been used, with the norm around 12 x 20 kilometers. This is roughly equivalent to the area of an M745 series 1:50,000 scale topographic line map of Germany.

b. **Off-line DTD requirements.** Before a CASTFOREM combat simulation can begin, the user is required to prepare the battlefield. One step in this preparation is to establish the physical layout of the battlefield using DTD. This is called off-line, pre-processed terrain data. This pre-processing of DTD is over and above the actual DTD requirements of the model itself. For example, a manual intelligence preparation of the battlefield (IPB) process is performed based on knowledge of the battlefield similar to that required of a battlefield commander preparing for actual battle. This is done before the actual combat simulation run is performed, and uses terrain information in either digital or analog form as a basis for decisions. Based on this terrain knowledge, the user specifies the value of the input variables used in the simulation model as discussed below.

(1) Maneuver Control Points (MCPs). An MCP is nothing more than a battlefield coordinate (X, Y, and Z) that has been given a unique numeric name. Movement of both ground and air vehicles is accomplished over movement networks which are composed of linked MCPs. These MCPs usually correspond to, or are based upon established road or transportation networks provided by DTD or manual map analysis.

(2) Avenues of Approach (AOPs). An AOP consists of MCPs that will represent a route of maneuver. The decision to establish AOPs is based on terrain intelligence that is provided prior to the simulation run, especially line of sight (LOS) analysis. The LOS is performed off-line prior to the simulation, and requires use of data provided from the ARTBASS DTD set or a manual process to produce comparable LOS information. Routes for avenues of approach are selected to minimize an attacking unit's exposure to direct fire systems as much as possible.

(3) Battle Positions (BPs) and Firing Points (FPs). A CASTFOREM BP consists of one or more firing positions; for moving units it also includes a start point (SP) and a release point (RP). When choosing static positions such as FPs within BPs, an off-line, line-of-sight analysis must be used to ensure that the unit using the position can actually see the areas of interest, as well as find out what it cannot observe. This off-line analysis is done prior to the combat simulation run using DTD supplied by the ARTBASS data base.

c. On-line DTD requirements. The major data types within CASTFOREM that use DTD are highlighted in the following paragraphs. The various data types and data files are referred to by the abbreviations and labels used in CASTFOREM.

(1) Battlefield data (BFLD-DATA). The purpose of this data type is to provide some of the initial physical battlefield parameters of the model. Several DTD requirements are found in this data type. DTD requirements are found in data files BF 10, BF 21/22, and BF 23.

(a) Data file BF 10 is used to designate the moisture condition (wet or dry) and the time of the year (summer or winter). This data must be specified by the user prior to the simulation run.

(b) Data file BF 21/22 is used to designate one of 16 surface features (i.e., agriculture, brushland, coniferous forest, orchard,

grassland, open water, built-up areas, etc.), their height, and their foliage during summer and winter seasons. The user selects the season, but the feature data is extracted from the ARTBASS DTD.

(c) Data file BF 23 pertains to obstacles and the obstacles' minimum heights. Five categories of obstacles are represented: road and railroad cuts and fills, natural linear features, walls and fences, other man-made linear obstacles, and military obstacles. This input data is extracted from the ARTBASS DTD.

(2) Terrain Data (TERRAIN-DATA). The purpose of the terrain data type is to provide digitized terrain data to CASTFOREM modules. The terrain data files are provided via nine pre-processed binary files which are prepared using data from the ARTBASS data base. Battlefield data descriptions (BFLD-DATA discussed above) must have been input prior to reading the terrain files, and the descriptors on the header of each terrain binary file must match the descriptors for the battlefield data. Each binary terrain file consists of many data elements. The data elements related to DTD requirements call for nine terrain codes for each cell: road type, surface features, vegetation or built-up area height, canopy closure, hydrography (rivers), CCM (dry), CCM (wet), elevation (m), and obstacles. These data elements have been supplied in the past by ARTBASS DTD.

(3) Object library (OBJECT-LIB). The purpose of the object data type is to insert objects that are used by the engineer and CSS modules. Objects such as craters and various types of minefields can be placed by the user into the combat simulation run using this data type. Two terrain requirements, soil strength and trafficability, are used when defining these object types. Currently, these data elements are not being used and are set to zero.

(4) Type of Units (TYPE-UNITS). The purpose of this data type is to define the generic units on the battlefield. The unit's size, vulnerability, sensors, personnel, fuel capacity, etc., are described in this data. Of the variables that must be defined for each unit, two are DTD-related: the TU30 card (cross-country speed data) and the TU32 card (road speed data). The TU30 card sets the cross-country speed for each unit based on its current grid cell location. The cross-country movement (CCM) speeds are obtained from ARTBASS DTD. The TU32 card sets the road speed appropriate for the unit's

current grid cell location. Currently, road speed data are manually input based on a map analysis of the road network in the area being modeled.

(5) Line of Sight (LOS). Intervisibility, or LOS is computed for two purposes: placement of BPs and FPs (see the discussion of off-line DTD requirements), and LOS detection between an observer and target. LOS detection algorithms are embedded in the computer code and are used on a continuous basis throughout the battle simulation. LOS is computed utilizing digitized terrain, taking into consideration ground elevations and vegetation heights for each grid cell, and other factors such as height of weapon or sensor, and obscuration data. CASTFOREM calculates LOS as uniform anywhere within a terrain cell. This means if LOS is possible from any point within the cell, then all points within that cell will be considered to have LOS.

d. Availability of DTD for CASTFOREM. CASTFOREM is currently using only ARTBASS and WES data sets. DTD coverage suitable for CASTFOREM to use is available for portions of the Federal Republic of Germany (FRG), Korea, Egypt, Jordan, and Costa Rica (see Appendix E-1). Additional coverage will become available as new ARTBASS data sets are produced under contract over the next three years. The adequacy of the available DTD to support CASTFOREM terrain requirements is discussed in paragraph 15.

13. VIC Model Description. This evaluation is based on information obtained from the VIC model documentation and interviews with persons familiar with the VIC model.⁶ VIC is a two-sided deterministic simulation of combat in a combined-arms environment. It represents land and air forces at the US Army corps level with a commensurate enemy force in a mid-intensity battle. The model is event-stepped for maneuver elements and time-stepped for calculation of support effects. It may be run in either an interruptible mode, or in a systematic batch mode. It has a series of pre-processors for constructing input data files and a comprehensive post-processor. VIC is executed through a series of modules which each represent a major function on the battlefield (see Figure E-3).

⁶Vector in Commander (VIC) Combat Simulation, Executive Summary, Model User's Guide, Post-processor User's Guide, and VIC Interactive Pre-processor (VIP) User's Guide, draft (TRAC-WSMR-TD, June 1987). Vector in Commander (VIC) Combat Simulation, Data Input and Methodology Manual, draft (TRAC-WSMR-TD, June 1987), and personal interview between Mr. Richard Taylor, ESC, and Messrs. Gamble, Porter, Lankford of TRAC-WSMR on 16 November 1987.

VIC MODULES

NUMBER	TITLE	ABBREVIATION
1	SYSTEM SPECIFICATIONS	SS
2	GLOBAL GROUND	GG
3	GROUND MOVEMENT	GM
4	ARTILLERY	AT
5	GLOBAL AIR	GA
6	AIR MAINTENANCE	AM
7	AIR-TO-GROUND ATTACK	AG
8	AIR INTELLIGENCE	AI
9	GROUND INTELLIGENCE	GI
10	FUSION INTELLIGENCE	FI
11	AIR DEFENSE	AD
12	DEFENSE SUPPRESSION	DS
13	ELECTRONIC WARFARE	EW
14	CHEMICAL	CH
15	open for expansion	
16	GRAPHICS DATA MODULE	GX
17	WEATHER DATA	WT
18	TERRAIN AND BARRIERS	TB
19	DECISION TABLES	DT
20	HELICOPTERS	HC
21	LOGISTICS	LO
22	COMMUNICATIONS	CO
23	RETURN TO DUTY	RD
24	POST-PROCESSOR	PT
25	MINEFIELDS	MF
26	AIR-TO-AIR	AA
27	FRONT LINE DETAILED ATTRITION	FL
28	SMOKE	SM
29	ENGINEERS	EN

Figure E-3

a. **DTD Representation.** Terrain is input to VIC in square grid cells. The data required for each cell represents four major terrain factors: vegetation, relief, area obstacles, and linear obstacles. These factors act in combination with maneuver unit factors to predict trafficability, line of sight, and visibility. The user of the model may specify the size of the grid cell; 4 kilometers by 4 kilometers is normally used. Special programs are provided in a pre-processor that will process digitized terrain at typical DTD resolutions (e.g., 25m, 50m, 100m) and synthesize it into the desired model cell resolution, in this case 4 kilometers by 4 kilometers. For example, previous runs of VIC have used a DTD set prepared by a contractor, which covered an area in West Germany that contained high-resolution data. In addition to setting the grid cell size, the user sets the size of the AO. Several sizes have been used in the past. A 150 km by 600 km area is a typical corps AO size used in VIC. This is about equivalent to six DMA 1:250,000 scale topographic line maps. The origin for the X and Y axes is determined by the user; the model will then read the location data in either X and Y coordinates or military UTM coordinates. Like CASTFOREM, VIC requires users to identify and define various terrain elements prior to running the simulation. Pre-processed DTD features are used for selecting avenues of approach, tactical areas, main supply routes, and barrier locations.

b. **Off-line DTD requirements.** Preparing a VIC combat simulation requires the use of off-line, pre-processed terrain data similar to CASTFOREM. This pre-processed DTD is over and above the actual DTD requirements of the model itself. A user must prepare the battlefield based upon a conceptual scenario. This is done before the actual combat simulation is performed. This DTD pre-processing takes place in the VIC Interactive Preprocessor (VIP). VIP constructs data input files and uses terrain information in digital form as a basis for graphical display. Based upon this terrain knowledge, the user selects required variables which are used in the simulation model and are addressed as a part of the VIP menu structure below.

(1) DTD is used by VIP to form the terrain displays that aid in preparing input to VIC. No one particular digital data base has been used exclusively; instead the best data available is used to cover the area of operations. As an example, the DTD provided by a contractor included a LOC network data base, a surface feature data base, and a terrain elevation data

base. The LOC network data base consisted of 14 vector formatted data features: autobahns, main roads, secondary roads, lightly surfaced roads, railroad lines, ferries, fords, heavy bridges, dams, road tunnels, rail tunnels, and three classes of rivers. The surface feature data base consists of: open areas, forest, urban, undefined areas, marsh, standing water, and heath. The terrain elevation data base was created from DMA DTED level I (rather than from the contractor DTD). This information was formatted to supply the required vegetation, relief, area obstacle, and linear obstacle data requirements of VIC.

(2) The VIP menu (Figure E-4) is used to build various parts of a scenario and create VIC input files. Several of these use DTD as a basis for decisions.

(a) Path point, route plan, network, and logistics menus allow the user to select and plan general AOPs, and transportation networks for combat and CSS units to follow. These menus use DTD, particularly transportation and elevation data, as a decision aid. Five classes of transportation data (autobahns, main roads, secondary roads, fair weather road, railways) and digital elevation data have been used in the past.

(b) Barrier and line obstacle menus allow the user to create and deploy area obstacles (sometimes referred to as barrier obstacles) and line obstacles (sometimes referred to as linear obstacles). The user defines obstacles based on the terrain displayed in VIP. The ability to overlay area obstacles on the terrain was developed to allow the portrayal of features such as urban areas and nuclear, biological, and chemical (NBC) contaminated areas. However, VIC now allows each terrain grid square to have its own trafficability code, and area obstacles are no longer treated as an overlay to the terrain. Instead they are represented by the trafficability and visibility codes given to individual terrain grid squares. Line obstacles are still input as line segments that are overlayed on the terrain independent of the underlying grid square system. This allows for accurate positioning of natural and man-made linear obstacles, such as embankments and antitank ditches, without being restricted to the grid pattern.

(3) In addition to using DTD in VIP (to support the development of VIC input files), DTD must also be processed to provide the terrain grid square data used by VIC in the actual execution of the model.

VIP MAIN MENU STRUCTURE

```

-- KEYWORD
-- HELP
-- UNIT ID GEN
-- UNIT MENU -- PATH PT MENU -- | -- TACTICAL MENU
-- SUBORDINATE MENU | -- RT PLAN MENU
-- COMMUNICATIONS MENU |
-- RT PLAN MENU - - - - -
-- MINEFIELD MENU
-- BARRIER MENU
-- LINE OB MENU
-- NETWORK MENU -- | -- LOGISTICS MENU
-- GRAPHICS
-- PARAMETERS
-- CHANGE PLANE
-- PLAYBACK
-- UTILITY MENU -- | -- GRAPHIC
-- TERRAIN
-- MENU
-- DEFINE
-- SLIDE

```

Figure E-4

c. On-line DTD requirements. VIC is executed through a series of modules (Figure E-3), each of which represents a major function on the battlefield. These modules consist of data requirements, which are further subdivided into data segments. Each segment represents a block of data which is required by VIC. The modules and data segments are referred to by the abbreviations and labels used in VIC.

(1) Terrain and Barriers (TB). There are four segments in the TB module that require the direct use of DTD. These segments load and list all data associated with terrain and barriers.

(a) TB-ONE contains basic information on the extent and classification of vegetation. There is no inherent limitation to the number of vegetation classes VIC can play, but currently four classes are portrayed: dense forest, light vegetation, grassland, and urban areas. This segment provides vegetation data that is used in several modules.

(b) TB-TWO performs four major functions and uses DTD elevation data as its basic source. First, it classifies relief into major categories: plains, hills, and mountains using a VIC terrain classification algorithm (see glossary for further explanation). Second, it performs visibility mapping which combines the vegetation type (taken from TB-ONE) and the relief type into three visibility levels: good, fair, or poor. Third, it performs trafficability mapping which also combines relief and vegetation into three trafficability levels of good, fair, and poor. Finally, this segment performs LOS and exposure distance mapping. The LOS parameter is used to compute the fractional LOS in that type of terrain. The mean exposure length is used to determine the average time a target remains visible.

(c) TB-THREE allows the user to place area obstacles on the current terrain mapping. There is no inherent limitation to the number of area obstacle classes VIC can play, but seven types of area barriers are identified in the documentation: rivers, passable features, impassable features, urban areas, chemical-, biological-, and nuclear-contaminated areas. This segment is not being used at this time. Instead area obstacles are represented through the trafficability codes assigned to each grid square.

(d) TB-FOUR allows linear obstacles to be placed on the battlefield. There is no inherent limitation to the number of linear obstacle

classes VIC can play, but currently, four major types have been designated: rivers, canals, tank ditches, and embankments.

(2) Ground Movement (GM). Segment GM-THREE computes six distinct data variables that are based upon information supplied in the TB module. The four major variables affecting the movement of ground combat units are: a combined trafficability table, an opposed speed table, combined weather/barrier visibility table, and a combined environmental/obscurant visibility table.

(a) The combined trafficability table is a 3 by 3 table which is used to combine the trafficability due to the weather (good, fair, and poor) with the trafficability due to terrain (good, fair, poor) to produce an overall trafficability (good, fair, and poor). This overall trafficability is then used as input to the opposed speed table.

(b) The opposed speed table is a 2 by 3 by 11 table which is used to determine the speed of a moving unit when in contact with an opposing force. Opposed movement is indexed by mobility (1=mounted, 2=dis-mounted), trafficability (good, fair, and poor from the combined trafficability table above), and kill ratios computed from opposing forces in contact.

(c) The combined weather/barrier visibility table is a 3 by 3 table used to combine the visibilities due to weather (good, fair, and poor) and terrain (good, fair, and poor) into an overall environmental visibility of good, fair, and poor.

(d) The combined environmental/obscurant visibility table is a 3 by 3 table used to combine the environmental visibility with the visibility level due to smoke, dust, and debris to form an overall visibility.

(3) Global ground (GG). Segment GG-ONE contains two data variables that are DTD-related but are user input.

(a) The maximum day speed is used to compute unit travel speeds. It is expressed in kilometers/hour which provides the speed for unopposed movement during daylight hours; it is also used as input to opposed speed calculations. Currently, this variable is user-specified. VIC does not use CCM speed or on road speeds derived from DTD to calculate this variable.

(b) Maximum night speed. The discussion in the previous section on maximum day speed applies for night speed also.

(4) Logistics (LO). Segment LO-THREE contains three data variables that are affected by transportation data contained in DTD. All are used to determine the effectiveness of the road network for logistics operations. All codes are currently input by the user. The transportation element in the DTD set is currently not used as an input source.

(a) The road surface code requires information on the road surface that can be obtained from the DTD. Four classes are described: concrete, bituminous, gravel, and dirt.

(b) The road width code allows the choice of two values for road width: roadways greater than 24 feet wide and roadways less than 24 feet wide.

(c) The road terrain code requires that four types of terrain be characterized: flat, rolling hills, hills with curves, and mountainous with the type of terrain affecting the road speed.

(5) Artillery (AT). AT-THREE allows the evaluation of the effects of terrain on lethal areas of artillery-round impact. This is done through the Minimum Lethal Area Factor Data input variable. This factor states that certain munitions will not be fired into a terrain type that has an associated terrain factor less than this parameter. Perfect terrain (plains with grassland) has a factor of 1.0.

(6) Air-to-ground (AG). AG-THREE allows the evaluation of the effects of terrain on the probability of detecting a target. Terrain can obscure or partially obscure geographic areas. This is done through the Probability of Target Detection Data input variable. This parameter is a function of visibility (good, fair, and poor) and a target priority.

d. Availability of DTD for VIC. Currently, DTD that can satisfy VIC requirements is available in two regions of the world: FRG and Korea. VIC is using the best available data for the areas it is now simulating. The adequacy of the available DTD coverage to support future VIC terrain requirements is discussed in paragraph 16.

14. FORCEM Model Description. This evaluation is based on a review of the FORCEM model documentation and interviews with persons familiar with the

model.⁷ FORCEM is a deterministic, average value model which is fully automated. There are no player interactions while the model is running. It is a completely two-sided model that operates on a time-step basis, representing the campaign in 12-hour time slices. Headquarters at corps, Army, and theater levels are represented. For each time step, the model cycles through a process to develop the combat situation for both sides; it makes decisions regarding actions to be taken by subordinate elements; it develops the combat and combat-support activities resulting from the decisions of both sides; it performs post-cycle status updates; and it produces output data for that time period.

a. **DTD Representation.** FORCEM represents terrain as square cells. The size of these cells is uniform within a terrain data set; however, the size of the cell can vary. Formerly 30 by 30 km cells were used, but 10 by 10 km cells are now being used. Each terrain cell is assigned the dominant terrain codes for each of eight directions into and out of the cell. Nine terrain types can be represented: oceans/lakes, low mountains, high mountains, rivers, cities, forests, roads, AOPs, and open terrain. Thus, each direction through a cell is digitized and coded according to the predominant natural or man-made feature in that cell. This procedure results in a detailed movement capability map that represents the difficulty of movement in each of the eight directions through the square. All runs of FORCEM have utilized terrain data that was manually encoded from map sheets at the 1:1,000,000 or 1:2,000,000 scale. DTD currently exists for the European, Korean, and Southwest Asia theaters. Superimposed on the terrain grid are logistics networks. Three types of logistics networks are represented: road, railway, and waterways. Major items of equipment and personnel flow along these networks. Materiel and personnel, as well as units arrive in the theater of operations through ports (both sea and air).

b. **Off-line DTD requirements.** Preparing a FORCEM combat simulation requires the use of off-line, pre-processed terrain data similar to that of

⁷FORCEM Evaluation Model Briefing Slides (CAA, March 1985); *Command and Control in the Force Evaluation Model* (CAA, 14 January 1986); *FORCEM Combat Service Support Module* (CAA, 20 February 1986); *The FORCEM Fire Support Module* (CAA, May 1986) and personal interview between Messrs. Taylor, Reynolds, and Halayko of ESC, and Mr. Wallace Chandler, CAA on 23 November 1987.

CASTFOREM and VIC. A user must prepare the battlefield based upon an operational plan. This is done before the actual combat simulation is performed. The battlefield representation, using terrain information in digital form, is a basis for decisions in the model. DTD is encoded by hand at CAA from tactical pilotage charts (TPCs), operational navigational charts (ONCs), and global navigation charts (GNCs), which are published at DMA. These CAA digital terrain files are then used as terrain input files to the model. As mentioned previously, the terrain in FORCEM now is represented using 10 by 10 km grid cells. The terrain features can be categorized into two functional areas: movement enhancements, and movement impediments. The movement impediments are features such as hills, mountains, forests, urban areas, rivers, lakes, and canals. Movement enhancement features such as roads and railways are also represented. Other features such as ports (airports and seaports) are also input prior to simulation by the user from map information.

c. **On-line DTD requirements.** Terrain and its representation in FORCEM is centered around a single theme: movement -- of units, personnel, equipment, and logistics. This movement centers around two categories of terrain features: LOCs and major surface features. This discussion centers on these features and how they are used in the model.

(1) Lines of communication (LOCs).

(a) Roads, railways, and waterways are the conduit for convoys, barges, and trains. These LOCs are encoded via the logistics networks. Units, supplies, and equipment moving along these networks are subject to interdiction and attrition. However, the networks themselves are not subject to damages. FORCEM does not distinguish certain features along the LOC infrastructure. For example, bridges and tunnels are not represented, nor are road classes (e.g., autobahn or two-lane roads). Petroleum, oil, and lubricants (POL) pipelines have been classified as a LOC feature in the past. However, FORCEM currently does not represent POL pipelines as a logistics network feature. POL pipelines (PPL) are assumed regardless of the lack of in-country facilities.

(b) From a functional standpoint, aerial ports of entry (airports) and seaports are identical. Seaports and airports are not extracted from a digital LOC file, but selected and input by the user prior to simulation. Materiel and personnel enter the theater through seaports and

airfields. Ports are FORCEM "units" and have defined capacities and capabilities that can be subject to damage. Damage to ports is represented as a function of the casualties to port personnel. Port facilities such as piers, quays, cranes, and covered storage are not explicitly represented, so facility damage is not directly measurable.

(2) Major surface features. There are eight major surface terrain features that can be represented in FORCEM: low mountains, high mountains, lakes/rivers, urban areas, forests, high-speed roads, AOPs, and open terrain. A lack of other vegetation classes makes it difficult to accurately represent the mobility impacts of other types of terrain such as marshes and swamps.

d. Availability of DTD for FORCEM. Adequate DTD is currently available from DMA to satisfy FORCEM's low resolution terrain requirements. The adequacy of the available DTD to support future FORCEM terrain requirements is discussed in paragraph 17.

IV. CONCLUSIONS

15. CASTFOREM. DTD is used off-line to make IPB decisions prior to running CASTFOREM, especially to plan LOS, MCPs, AOPs, and BPs. DTD is used on-line to provide various model parameters for the computation of LOS and trafficability. ARTBASS DTD is currently used to satisfy the majority of CASTFOREM's DTD requirements (100-meter cell resolution).

a. CASTFOREM could make better use of existing DTD sources by replacing some data that is now manually input with data that is automatically processed from available DTD sources (some specific examples are given in Section V., RECOMMENDATIONS).

b. The need for DTD to support CASTFOREM is dependent on the studies that will use the model. However, ESC's assessment of how CASTFOREM is used leads us to the conclusion that existing DTD coverage, along with the additional areas being produced in ARTBASS format through ETL and WES, will be adequate to meet most CASTFOREM requirements. To use CASTFOREM to test battalion and smaller unit doctrine, tactics, force structure, and equipment, it is not necessary to run the simulation over every piece of terrain in the world where US battalions could fight. Except for special studies that need to play a specific geographic location or a unique type of terrain for which no DTD exists, the available DTD provides an adequate sample of different terrain types to represent the kinds of terrain situations US forces are likely to face.

16. VIC. VIC demonstrates an effective use of relatively high-resolution DTD as an off-line decision aid. The off-line DTD is used as input to a preprocessor that develops the low-resolution input required by the model itself (e.g., 100m spacings between elevation points are used as a base for terrain classifications of plains, hills, and mountains in low-resolution, 4 km cells).

a. VIC could make better use of existing DTD sources by replacing some data that is now manually input with data extracted from available DTD sources (some specific examples are given in Section V., RECOMMENDATIONS).

b. The need for DTD to support VIC is dependent on the specific studies that will use the model. If VIC is used only to study broad doctrine and force structure questions, then a small array of terrain data sets that

cover the general types of terrain US corps are likely to have to fight on, is adequate to meet VIC's needs. However, middle level resolution models like VIC can and are used to analyze specific contingency planning issues. To be responsive to the need for analysis of corps operations in a particular area, DTD must be available for that specific area. The current delays in producing DTD mean that terrain coverage requirements must be planned well in advance for the data to be available when it is needed. The requirements for DTD to support VIC are not sufficient justification to generate an urgent need for new DTD production. But, the terrain areas that are of interest to the modeling community are the same areas where DTD is needed to support the fielding of new Army weapons and battlefield command, control, communications, and intelligence (C³I) systems. VIC users must be aware of the coverage and formats of the DTD being produced for these new systems so they can make use of it in VIC when it becomes available.

17. FORCEM. DTD, currently used by FORCEM, is generated manually at extremely low resolutions by in-house personnel at CAA for both off-line decision making and a few on-line simulation decisions.

a. This in-house manual DTD generation could be eliminated by developing the ability to use existing DTD files to support FORCEM (this initiative is discussed in Section V., RECOMMENDATIONS).

b. Until CAA develops a preprocessor that can use digitized terrain input, there are no requirements for the production of new DTD coverage for FORCEM. Once a preprocessor is developed, the available DTED and DFAD coverage will satisfy FORCEM terrain requirements. However, the limitations of DFAD representation of LOC networks means CAA will still have to do some manual coding of LOC information until DMA produces the new standard DTD products.

V. RECOMMENDATIONS

18. Make Increased Use of DTD. Each of the models examined is manually entering terrain data that could be obtained from existing DTD sources.

a. CASTFOREM makes good use of DTD; efforts should continue to automate the extraction of additional terrain feature data from existing DTD files. For Example, TRAC-WSMR should:

(1) Use ARTBASS modified unified soil classification data to determine soil strength for OBJECT-LIB requirements.

(2) Use ARTBASS CCM data to supply trafficability data for OBJECT-LIB requirement.

(3) Use WES-Mobility AMM data to provide on-road speed data to the TU32 road speed card via the road code attribute for each cell. Currently, ARTBASS DTD only provides road classifications, not the speed for a distinct road type.

b. VIC and its preprocessor VIP make good use of DTD; efforts should continue to automate the extraction of additional terrain feature data from existing DTD files. For Example, TRAC-WSMR should:

(1) Use WES-Mobility AMM DTD to derive maximum day and night speeds (both CCM and road speeds) in the GG module.

(2) Use WES-Mobility AMM DTD to supply road surface codes, road width codes, and road terrain codes for the LO module.

c. FORCEM uses manually generated terrain input; efforts should be undertaken to automate the extraction of terrain data from existing DTD files. To reduce this manual effort CAA should:

(1) Develop an off-line DTD preprocessor (similar to VIP) to prepare terrain input for FORCEM.

(2) Use DMA's DFAD and DTED data as sources of DTD to satisfy current FORCEM requirements and to open the way for new standard DTD (including better LOC information) to be used in the future.

19. Make Model DTD Compatible With Tactical DTD. The generation of new DTD should be driven primarily by the requirements of new tactical weapons and C³I systems, not by model requirements. However, the areas where DTD is needed for the new tactical systems are also the areas where model analysis will be needed. Therefore, when DTD is produced in the new standard formats

for tactical systems, it is important for the models to be able to read and extract the data they need.

a. CASTFOREM; The existing ARTBASS terrain data sets, plus the new data being produced by WES, will offer sufficient variety to support most CASTFOREM study requirements. However, there will certainly be special study requirements that need specific terrain locations not covered by the DTD produced in ARTBASS format. To be able to quickly respond to special study requirements, changes should be made to allow CASTFOREM to use new DTD formats. Extraction programs to convert other sources of DTD to ARTBASS format would give CASTFOREM access to new areas of coverage as they become available. While TRAC-WSMR could develop such extraction programs, ESC recommends ETL perform this task (in-house or through contract) since it should support not only CASTFOREM, but the ARTBASS system as well.

b. VIC: Because VIC has the greatest potential for use on studies of different geographic areas, it has the greatest need for additional terrain coverage. TRAC-WSMR should give priority to adapting VIP extraction programs to be able to read new DTD formats so that new coverage is available for use as soon as it is produced.

c. FORCEM: The key to supporting FORCEM with DTD is for CAA to develop a preprocessor to extract DTED and DFAD data and convert it to a form usable by FORCEM (see paragraph 18c). The existing DTED and DFAD resolution and coverage is adequate for current FORCEM needs, except for LOC network descriptions. The proposed new standard DTD products will have this LOC data. And, the design of the FORCEM preprocessor should allow for the use of new DTD sources as they become available.

20. Integrate DTD Requirements. ETL included the needs of the Army analysis community in their 1984 study, *Army Digital Topographic Data Requirements*. These requirements were validated by ODOSINT and were formally presented to DMA in October 1984. As discussed in paragraph 3 at the beginning of this Annex, the Army must establish its most critical DTD needs (those that cannot wait for the new DMA system) and develop a cost effective method of producing this urgently needed data.

a. In the past, Army modelers have funded DTD production by engaging contractors and government agencies such as WES, to meet model requirements not met through standard DMA terrain products. Such a case-by-

case approach may meet the immediate needs of a particular model as used on a particular study. However, this shortsighted approach can lead to a proliferation of data base formats, unnecessary duplication of coverage, and needlessly expensive production costs. To avoid forcing modelers to resort to such measures, ETL must establish standards and specifications for the Army's interim terrain product needs, and then require that all new production efforts follow these standards. Fortunately, ETL is organized to do just that. ETL's Terrain Analysis Center (TAC) has the mission of terrain data production to meet Army requirements not met by DMA, and ETL's Concepts and Analysis Division (CAD) has been tasked to define the standards and specifications for interim DTD products. Unfortunately, ETL does not presently have either the priority or the resources to support such a program.

b. The study programs of the agencies using CASTFOREM, VIC, and FORCEM will determine the specific DTD coverage required to support these models. It is beyond the scope of this analysis to define those study programs. But, ESC believes VIC will have the greatest need for additional DTD production -- the available ARTBASS DTD and DTD being produced by WES will give CASTFOREM a variety of terrain types on which to investigate battalion-level combat; and CAA has terrain coverage for the theaters it normally uses for FORCEM. As discussed in paragraph 16b, the geographic areas requiring DTD for new tactical weapons and C³I systems will also be of interest for use in VIC-supported studies. To support both the fielding of the new Army systems that require DTD and the use of VIC to support the analysis of corps-level operations, it will be necessary to develop DTD for all areas covered by US corps operation and contingency plans. To get a first approximation of the level of effort involved in producing this amount of new DTD, ESC asked ETL to develop a rough estimate of the time and cost required to produce an interim set of DTD from available source materials. ETL estimates the production of interim terrain data from existing hard copy TTADB coverage would require about 30 staff years, and would cost about \$2 million (see Figure E-5).⁸

⁸An Investigation of Resource Needs for Production of Digital TTADBs/PTADBs in Support of Army Requirements for ITD, working paper (ETL, March 1988); and personal interviews between Mr. Reynolds of ESC and Mr. Richard Herrmann of ETL on 9 and 10 March 1988.

DTD RESOURCE REQUIREMENTS BY REGION

GEOGRAPHIC REGION	STAFF YEARS	DOLLARS (in millions)
EUROPE	14.5	1.0
WESTERN PACIFIC	8.3	0.5
AFRICA/MIDDLE EAST	2.0	0.1
CENTRAL AMERICA/ CARIBBEAN AND OTHER	5.0	0.3
TOTAL	29.8	1.9

Figure E-5

c. ESC is not in a position to establish the Army's priority for new DTD production (those priorities must be set by the Deputy Chief of Staff for Intelligence, in cooperation with the Deputy Chief of Staff for Operations). Also, ESC believes that the needs of new tactical systems should be the primary consideration in setting the priorities for new DTD production. However, from the perspective of model requirements alone, ESC suggests priority be given to digitizing the TTADB source material, since it has the terrain feature information and data density most appropriate to VIC. ESC also recommends that the production of new DTD be scheduled in the following order based on the relative priority of modeling efforts in each geographic area (see Figure E-6):

(1) Europe -- Since studies are most often designed to test US doctrine, tactics, and equipment against the most demanding mid-intensity threat, the most often required scenario involves modeling a NATO versus Warsaw Pact conflict in Europe. It is also likely that further arms reduction negotiations will generate urgent new requirements to analyze US combat

DTD DEVELOPMENT SCHEDULE

GEOGRAPHIC REGION	FY89	FY90	FY91	FY92
EUROPE				
WESTERN PACIFIC				
AFRICA/MIDDLE EAST				
CENTRAL AMERICA/ CARIBBEAN & OTHER				

Figure E-6

capabilities in Europe. If FORCEM begins to use VIC as a source of corps-level battle outcomes (as recommended in ANNEX C), DTD will be needed for all NATO corps sectors, not just the US corps sectors. Using ETL's estimates of 120 manhours and a cost range of \$3,000 to \$4,200 per map sheet, the available TTADB coverage of 233 map sheets in this area could be digitized by committing about 14-1/2 manyears (27,960 manhours) and something under \$1 million (\$699,000 to \$978,600).

(2) Western Pacific -- With US forces forward deployed and operating under a combined command with the Republic of Korea (ROK), this is the next area where DTD is most needed to support combat models. The Deputy Undersecretary for Operations Research has approved the release of VIC to the ROK/US Combined Forces Command, and they will need DTD to run the model. Appendix E-1 shows that high resolution DTD coverage of Korea is limited. The most urgent requirement is for additional DTD coverage of the Demilitarized Zone (DMZ), but coverage must eventually be extended to include the entire Korean peninsula. Using ETL's estimates of 120 manhours and cost range of

\$3,000 to \$4,200 per map sheet, the available TTADB coverage of 134 map sheets in this area could be digitized by committing something over eight manyears (16,080 manhours) and about \$.5 million (\$402,000 to \$562,800).

(3) Africa/Middle East -- Constantly changing conditions in the Central Command's area of responsibility make it important for the modeling community to be able to support contingency planning in this volatile area. Appendix E-1 shows that only a few countries in this area have any high-resolution DTD coverage, and that coverage is limited to a few locations in each country. Using ETL's estimates of 120 manhours and cost range of \$3,000 to \$4,200 per map sheet, the available TTADB coverage of 32 map sheets in this area could be digitized with two manyears of effort (3,840 manhours) and about \$100 thousand (\$96,000 to \$134,400).

(4) Central America/Caribbean -- As with the Central Command, volatile conditions throughout most of Southern Command's area of responsibility make it important for the modeling community to be able to support Southern Command study needs. Using ETL's estimates of 120 manhours and cost range of \$3,000 to \$4,200 per map sheet, the available TTADB coverage of 80 map sheets in this area could be digitized with five manyears of effort (9,600 manhours) and between one-quarter and one-third of \$1 million (\$240,000 to \$336,000).

(5) Other -- There are certainly other areas throughout the world where contingency missions might occur (e.g. islands in the Pacific). But, the requirement for modeling analysis (particularly VIC-level analysis) is presently not high in these areas.

APPENDIX E-1

DTD COVERAGE WORLDWIDE

Map of Israel and Occupied Territories with a grid overlay. The map shows major cities like Jerusalem, Tel Aviv, Haifa, and Gaza. A grid of numbers (e.g., 5887, 5987, 6087, 6187) is overlaid on the land area. A large 'X' marks a specific area. The text 'P777' is prominently displayed in the center. The map is labeled 'ISRAEL' and 'JORDAN'.

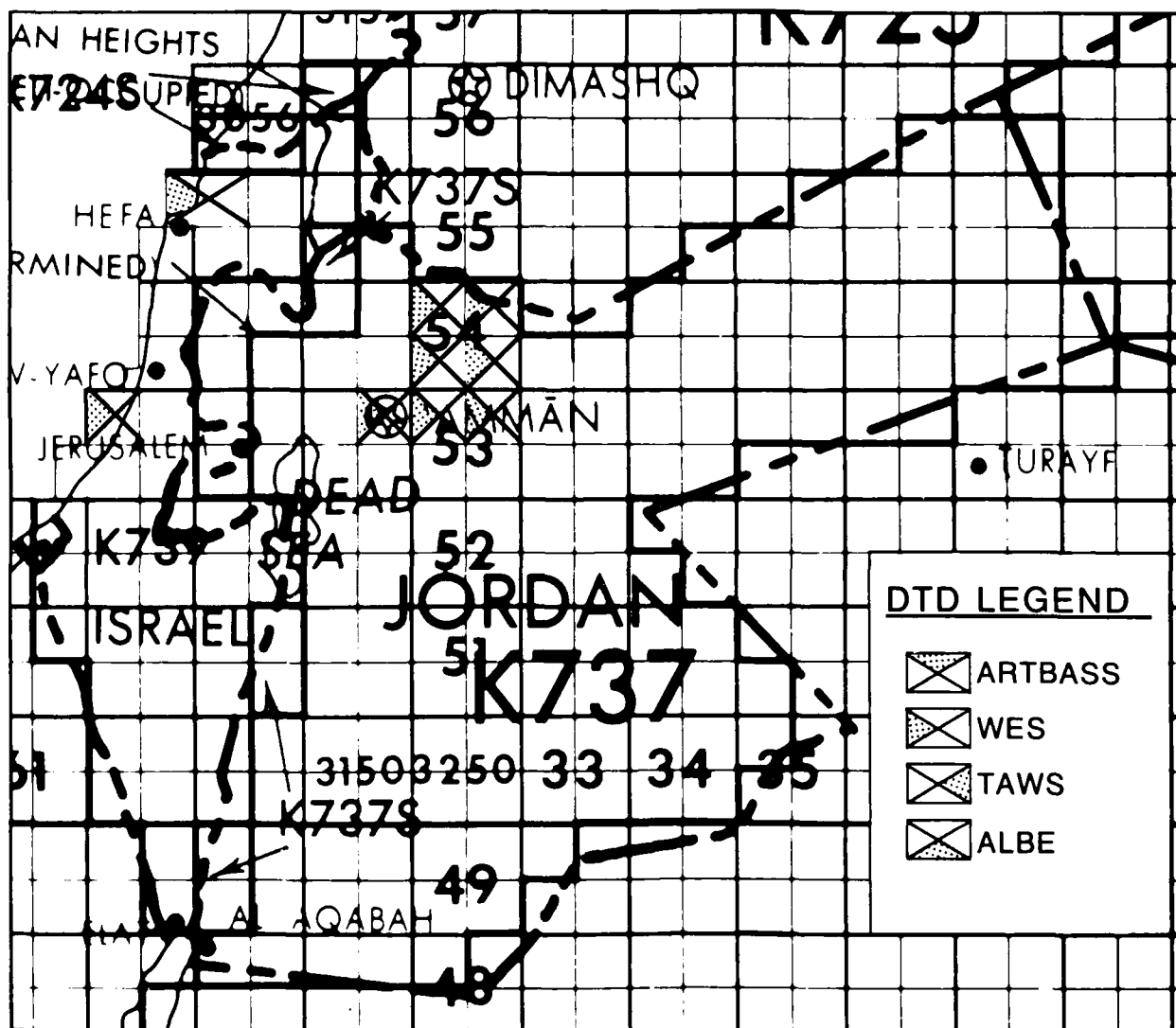
Army DTD Production in Israel and Jordan

JORDAN

<u>Quad No.</u>	<u>Quad Name</u>
3254 IV	Al Mafrāq
3254 I	Khīrbat um el Jīmā
3254 III	Az Zarqā
3254 II	Qaṣr az Hallabat
3153 I	Amman
3253 IV	Sahab
3253 I	Qaṣr Mushash

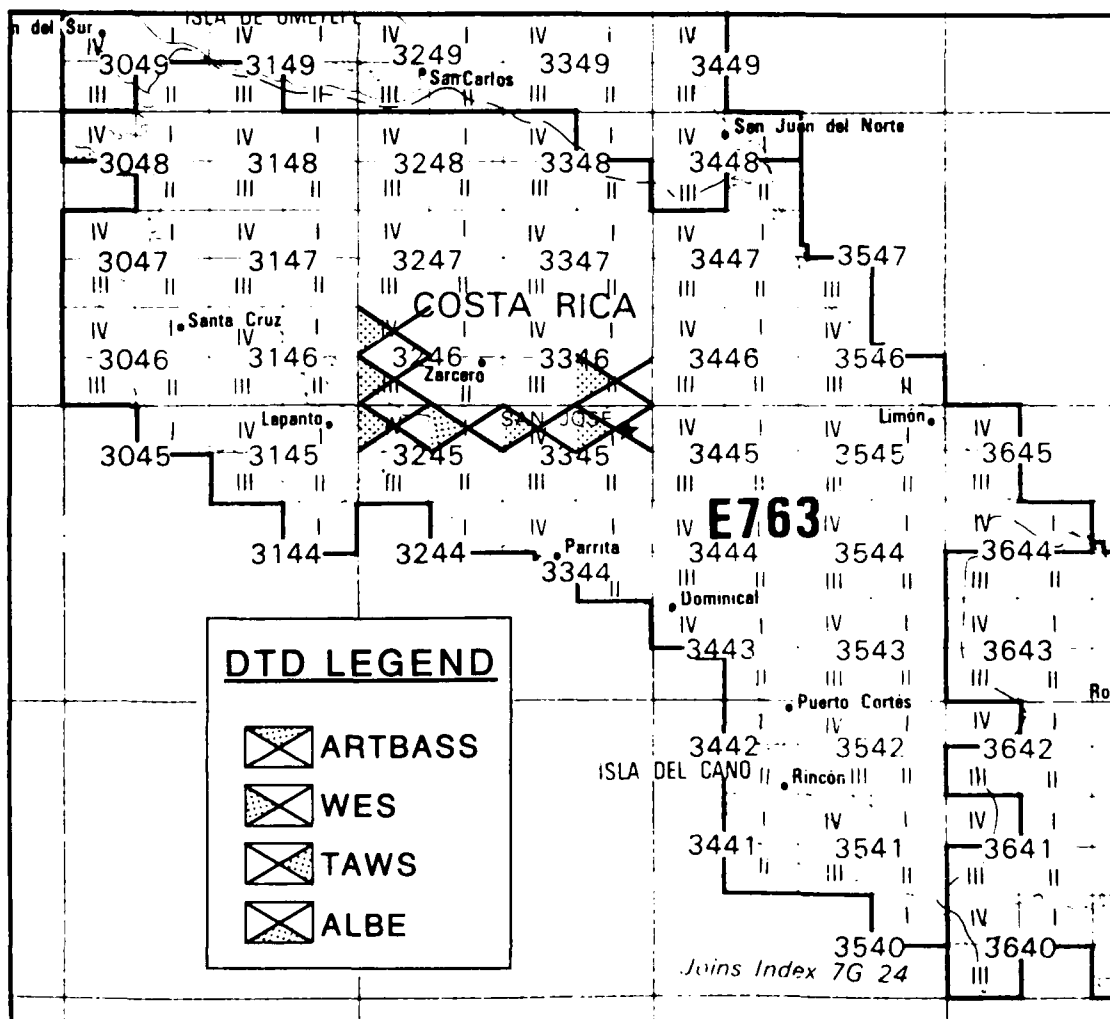
ISRAEL

<u>Quad No.</u>	<u>Quad Name</u>
2953 IV	Yavne
3055 IV	Acre

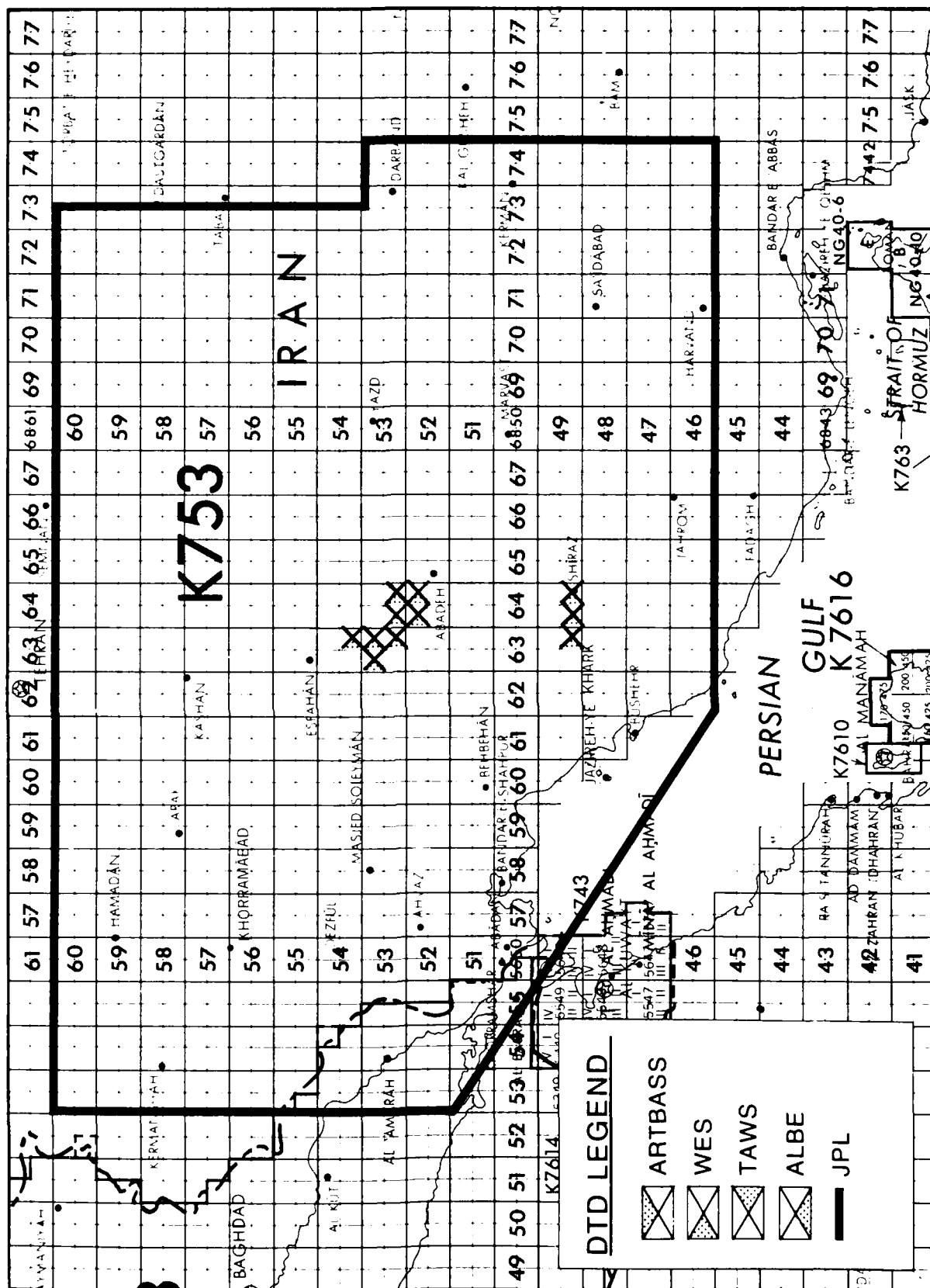


Army DTD Production in Costa Rica

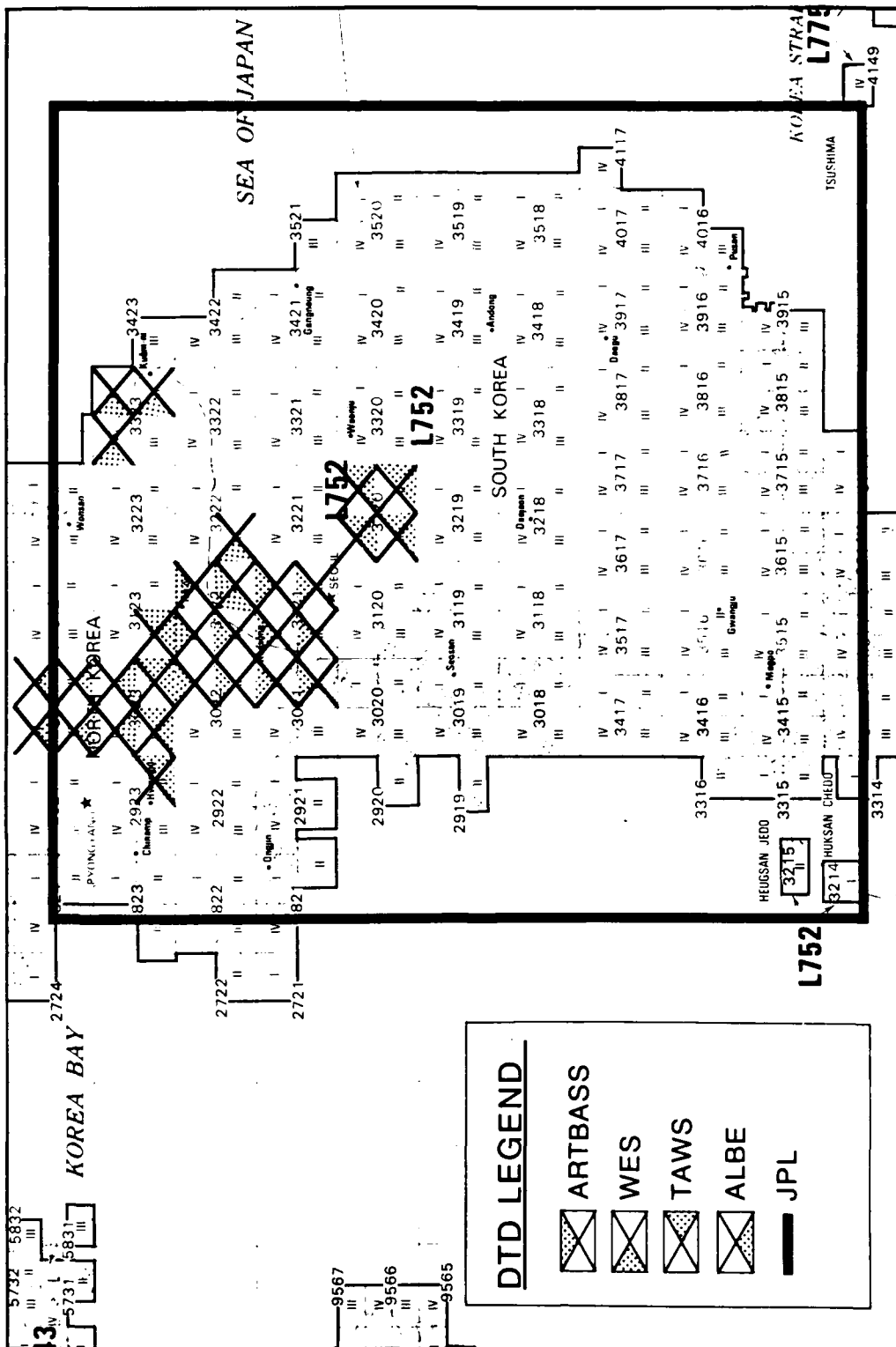
Quad No.	Quad Name
3245 I	Barranca
3245 IV	Golfo
3246 III	Chomes
3246 IV	Juntas
3345 I	Abra
3345 IV	Santiago
3346 II	Miramar



Army DTD Production in Iran



Army DTD Production in the Republic of Korea (ROK)

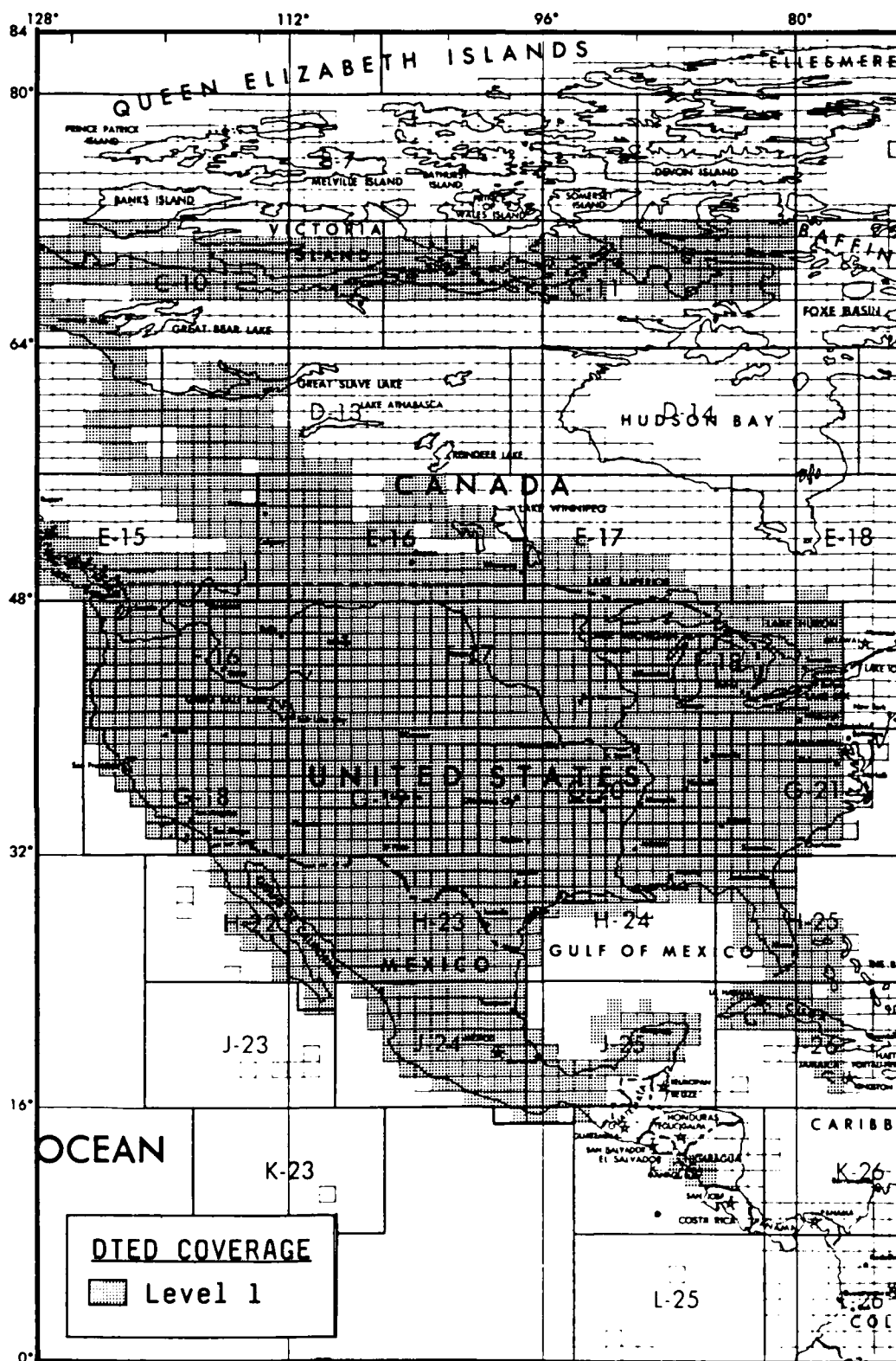


DTD LEGEND

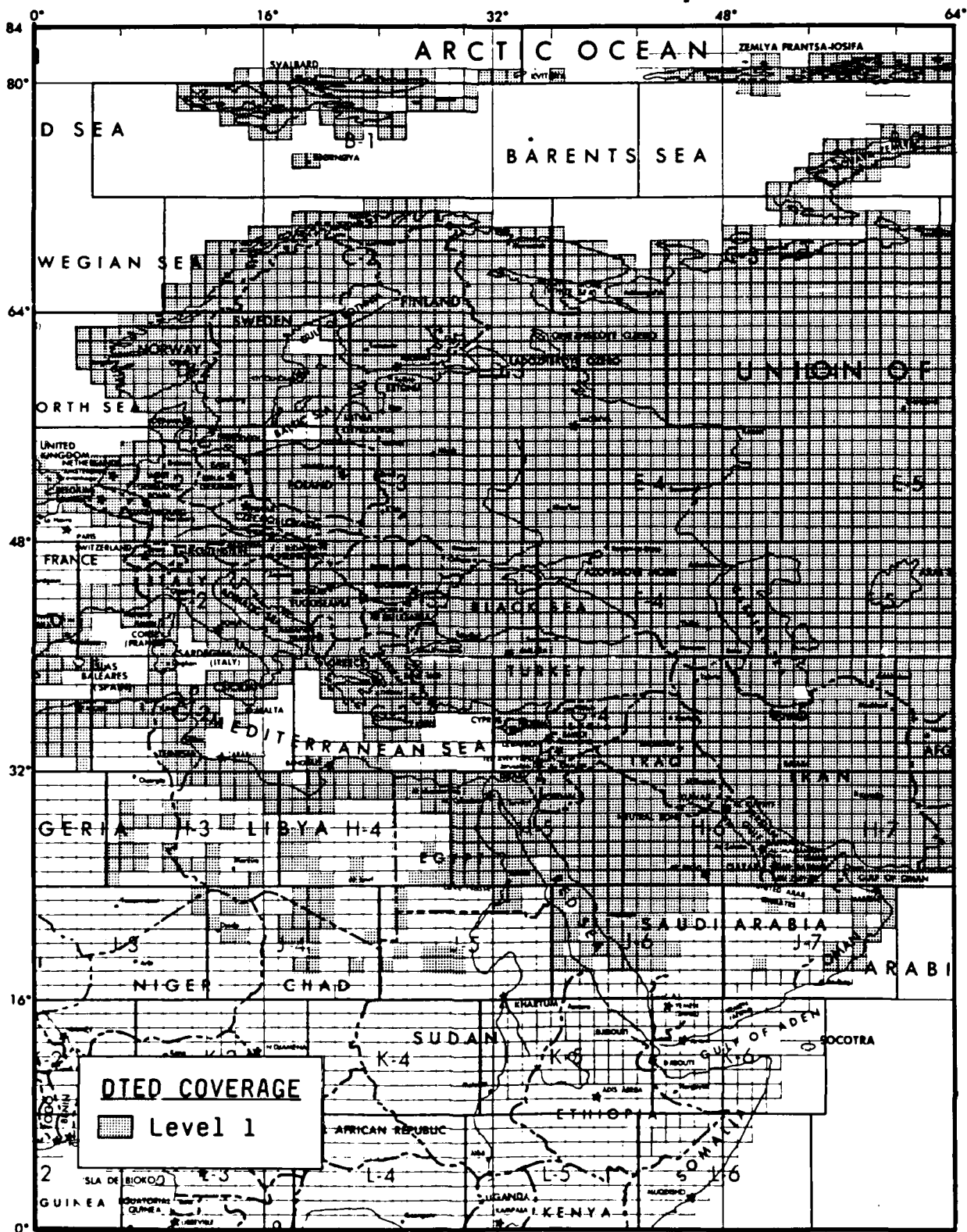
- ARTBASS
- WES
- TAWS
- ALBE
- ITD
- BDM
- CATTS
- SPECIAL DTD

Map Labels: EAST GERMANY, WEST GERMANY, M745, M745-1, M745-2, M745-3, M745-4, M745-5, M745-6, M745-7, M745-8, M745-9, M745-10, M745-11, M745-12, M745-13, M745-14, M745-15, M745-16, M745-17, M745-18, M745-19, M745-20, M745-21, M745-22, M745-23, M745-24, M745-25, M745-26, M745-27, M745-28, M745-29, M745-30, M745-31, M745-32, M745-33, M745-34, M745-35, M745-36, M745-37, M745-38, M745-39, M745-40, M745-41, M745-42, M745-43, M745-44, M745-45, M745-46, M745-47, M745-48, M745-49, M745-50, M745-51, M745-52, M745-53, M745-54, M745-55, M745-56, M745-57, M745-58, M745-59, M745-60, M745-61, M745-62, M745-63, M745-64, M745-65, M745-66, M745-67, M745-68, M745-69, M745-70, M745-71, M745-72, M745-73, M745-74, M745-75, M745-76, M745-77, M745-78, M745-79, M745-80, M745-81, M745-82, M745-83, M745-84, M745-85, M745-86, M745-87, M745-88, M745-89, M745-90, M745-91, M745-92, M745-93, M745-94, M745-95, M745-96, M745-97, M745-98, M745-99, M745-100.

DTED Production in the Americas

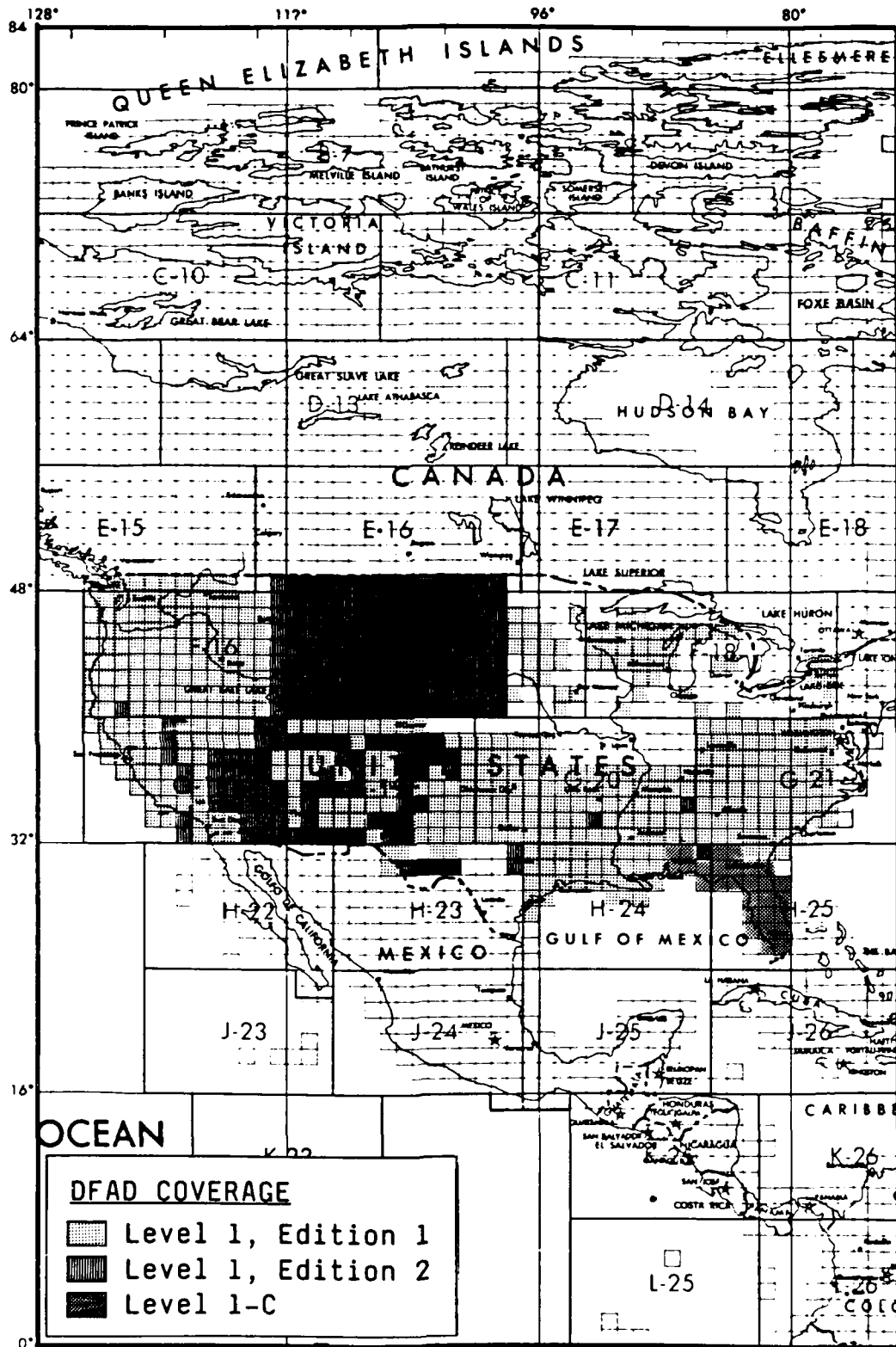


DTED Production in Europe

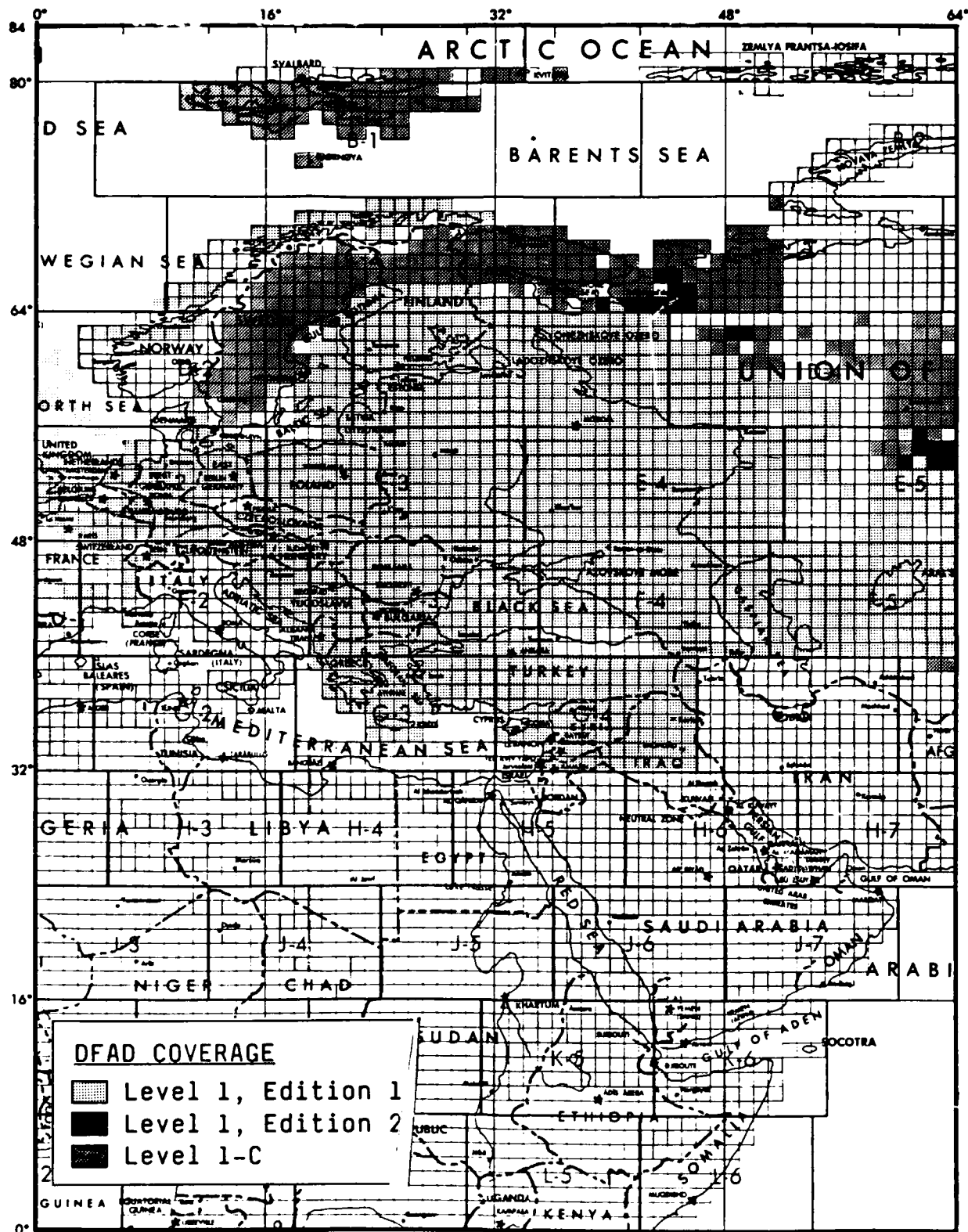


The map displays the North Pacific Ocean region, bounded by the Arctic Ocean to the north, the East Siberian Sea and Bering Sea to the west, and the Philippine Sea and North Pacific Ocean to the east. The coastline of Alaska is visible on the left, while the coastlines of Russia, Japan, and the Philippines are shown to the south and east. A grid of latitude and longitude lines is overlaid on the map. A legend in the upper right corner indicates that the shaded areas represent "DIED COVERAGE Level 1". The shaded regions are concentrated in the central and eastern North Pacific, particularly around the Japanese archipelago and extending southwards. Various geographical features and islands are labeled, including the Sea of Okhotsk, Japan Sea, and Philippine Sea. The map also shows the coastlines of Alaska, Russia, Japan, and the Philippines.

DFAD Production in the Americas



DFAD Production in Europe



DFAD Production in Asia

DFAD COVERAGE

- Level 1, Edition 1 (hatched pattern)
- Level 1, Edition 2 (solid black)
- Level 1-C (dotted pattern)

Geographic Labels: ARCTIC OCEAN, LAPTEV SEA, EAST SIBERIAN SEA, BERING SEA, SEA OF OKHOTOSK, SEA OF JAPAN, PHILIPPINE SEA, NORTH PACIFIC OCEAN, KAMCHATKA PENINSULA, KURIL ISLANDS, JAPAN, PHILIPPINES, MARIANA ISLANDS.

DFAD Numbers: D-10, D-11, F-10, F-11, H-12, H-13, H-14, H-15, J-12, J-14, J-15, J-16, J-17, J-18.

E-1-12

APPENDIX E-2

GLOSSARY OF TERMS

APPENDIX E-2

GLOSSARY OF TERMS

AirLand Battlefield Environment (ALBE) Program. USACE has instituted the ALBE program to focus upon two activities. One, to provide the Army material acquisition activities with the capability of assessing and exploiting realistic battlefield environmental effects. Second, to provide the Army in the field with the capability to assess and exploit battlefield environmental effects for tactical advantage. Demonstrations of the ALBE program have been conducted recently on Fort Hood (1986) and in Korea (1987). These preliminary demonstrations have used a computer test bed system to produce tactical decision aids (TDA) to help the battlefield commander make better decisions. The ALBE test bed system uses a GIS which processes DTD. This GIS uses a digital data base, using digitized information from TTADBs and other sources.

Areal Feature. An area completely enclosed by a delimiting line of the feature manuscript.

Army Training Battle Simulation System (ARTBASS). ARTBASS can model a tactical environment which can encompass a surface area of 500 square kilometers to an altitude of 10 kilometers. The ARTBASS is capable of modeling a total of 200 units simultaneously during a simulated exercise. Natural environmental factors are included in the model, for example: weather, vegetation/forestation, ground surface, soil type, wind, and visibility. Each DTD data base created for use on ARTBASS is produced in a 64-bit fixed field, raster format with Universal Transverse Mercator (UTM) coordinates using 12.5 or 25-meter post spacing. The actual digital scale is 1:49,212. The ARTBASS DTD set consists of a UTM digital terrain elevation data (DTED) file, a vegetation feature file containing the vegetation type, canopy closure, height, a surface material file, a surface drainage file, an obstacle file, a transportation file, and a CCM file for several vehicles, both wet and dry.

Collateral Sources. Outside agencies, both national and foreign, from which information and data may be obtained.

Critical. Failure of unit operations; increased probability of defeat; paramount to success in pivotal situations.

Data Base (DB). An organized set of evaluated MC&G data stored in either graphic, textual, or digital form. A data base may contain one file of data (DTED), or several data files.

Digitize. To translate an analogue measurement of data into a numerical description expressed in digits in a scale of notation.

Digital Data. Data represented by digits, perhaps with special characters and the space character.

Digital Data Base (off-line). A digital data base maintained in a common format that supports different user systems. Normally, the data must be transformed before they can be used by a specific user system.

Digital Data Base (on-line). A digital data base in the format needed by a user system and which can be directly loaded into the used system. This term is commonly referred to as the on-line data base.

Digital Feature Analysis Data (DFAD). DFAD Level I consists of selected natural and man-made planimetric features, type classified as point, line, or area features as function of their size and composition. The data is stored in polygon formate and segregated into 1 degree X 1 degree geographic cells. DFAD level 1 is available in several levels and editions.

Digital Landmass System (DLMS) Data Base. DLMS contains two digital data bases, Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD), and generally has an accuracy and resolution similar to a 1:250,000 scale topographic line map.

Digital Map. A map expressed and stored in digital form. It can also be a representation in digital form of discrete points on the earth's surface. Also called a numerical map.

Digital Terrain Data (DTD). DTD is a generic term used to describe any machine readable file and or data base of topographic data, either feature data, elevation data, or both. DTD is commonly used to refer to DLMS, DFAD, DLMS DTED, TTD, STD.

Digital Terrain Elevation Data (DTED). DTED Level I consists of a uniform matrix of terrain elevation values. The standard DTED file size is a 1 degree X 1 degree cell. Each elevation data record contains 1201 elevation values along a single meridian with 3 arc seconds (latitude) spacing. Elevation posts are spaced approximately every 100 meters.

Digital Terrain Elevation Matrix. Elevation posts, non-specific with respect to editing and smoothing, and evenly distributed in a rectangular pattern.

Digital Terrain Model. A statistical representation of the continuous surface of the earth by a large number of selected points with known X,Y, Z coordinated in an arbitrary coordinate field.

Digital Topographic Data (DTD). A generic term used to describe the combination of both elevation and feature data (see also Digital Terrain Data).

Digital Topographic Support System (DTSS). The DTSS will put the speed and flexibility of automation to work for the terrain analyst. DTSS will supply digital topographic support for the field Army in the 1990's. It will supply data for such tactical users as the all-source analysis system, and the FIREFINDER counter artillery counter-mortar radar.

Environment. Consists of five elements: atmosphere, terrain, battlefield induced contaminants, background signature, and illumination.

Elevation Post. A point with known horizontal and vertical position with respect to some defined reference system.

Feature Analysis. The process of locating, examining, and classifying the physical characteristics of natural and cultural features on the earth's surface.

Feature Extraction. The process of transferring or encoding feature analysis data to a digital or analog mode.

Feature Type. A classification of feature into categories of point, linear (line) or areal features.

Geodetic Datum. A particular association of an ellipsoid to some physical monument on the earth. It represents the fixing of an origin and the orientation from which location on the earth is measured.

Grid. A reference system applied to maps to provide a uniform system for referencing and making measurements.

Interim Terrain Data (ITD). ITD will consist of digitized TTADB's and PTADB's, together with DTED Level I. ITD format and content will be designed to allow it to meet interim Army needs until DMA can produce TTD. To the extent possible, ITD will be designed to be a compatible subset of TTD, so that systems using ITD can easily transition to TTD when it becomes available.

Linear Feature. A feature that is portrayed by a line that does not represent an area.

Near-Term Requirement. A DTD requirement generated by an operational system to be fielded in the FY 1987-FY 1993 time period.

Mid-Term Requirement. A DTD requirement generated by an operational system to be fielded in the FY 1993-FY 2002 time period.

Far-Term Requirement. A DTD requirement generated by an operational system to be fielded in the FY 2002-FY 2011 time period.

Operational System. A system that has passed the first unit equipped state of development and is either fielded or in the process of being fielded.

Planning Terrain Analysis Data Base (PTADB). The PTADB is a set of hard copy overlays keyed to a 1:250,000 scale topographic line map. The PTADB is limited to a few key natural and man-made features used to satisfy military planning requirements. These features include: surface configuration (slope), vegetation, surface materials, surface drainage, transportation, obstacles, and water resources.

Point Feature. An object whose location can be described by a single set of coordinates.

Resolution. A measure of the smallest possible difference in value or position. In a computer system, this may be numerical resolution or physical resolution of the hardware; e.g., plotter step size or digitizer resolution.

Raster. A regular, two dimensional arrangement of physical or conceptual elements; e.g., addressable points. Sometimes synonymous with grid, and also matrix.

Special Terrain Data (STD). STD contains elevation and feature data sets similar to TTD. This data base, however, is much more detailed and accurate than TTD, with resolution requirements relatively equivalent to a 1:12,500 scale topographic line map and associated terrain analysis products. While STD is a stated Army requirement, DMA has said it will not address this requirement until after the Mark 90 system is operational and TTD requirements are being met.

Tactical Terrain Analysis Data Base (TTADB). The TTADB is a set of hard copy topical overlays keyed to a 1:50,000 scale topographic line map. This data base is limited to those natural and man-made features of tactical military significance. These features consist of surface configuration (slope), vegetation, surface materials, surface drainage, transportation, and obstacles.

Tactical Terrain Data (TTD). TTD is a data set similar in content, accuracy, and resolution to a Class B, 1:50,000 scale topographic map/terrain analysis study. TTD will contain unsynthesized and unsymbolized feature and attribute data, plus elevation data. Feature and attribute data will include information about the size, shape, location, and height of extracted features. The elevation matrix will contain elevation posts every 30 meters (1 arc second) referenced to the World Geodetic system. TTD is considered the Army's operational support data base and will meet most user requirements when it becomes available. However, DMA will not begin producing TTD until the Mark 90 system becomes operational.

Terrain Analysis Work Station (TAWS). TAWS is a prototype of the DTSS. TAWS includes four major components: data base development, terrain analysis and product generation, intervisibility analysis and product generation, and environmental effects software. The data base development is a terrain analysis data base which typically includes factor overlays covering soil, drainage, transportation, vegetation, slope and obstacles.

Terrain Modeling. The mathematical modeling of the physical shape of a portion of the earth's surface (terrain) by fitting functions to the elevation data.

Transformation program. A computer program used to change digital data from one format to another (e.g., from planar to DMA standard).

Vital. Jeopardizes the existence of the division; high loss of life, and early defeat of the unit.

VIC Terrain Classification Algorithm. VIC classifies relief into three classes: mountains, hills, and flat areas. This is accomplished by a three-step process. First DTED is read, reduced, and synthesized into a cell (4 km X 4 km) value. Second, cell values are then referenced to a terrain look-up table based on the Natick Landform classification system. This system describes surface roughness within a landform compartment by specifying three characteristics: maximum local relief, modal local relief, and average number of positive features per unit distance. A code is assigned based on these characteristics. Finally, these codes are then reduced to a plains, hills, or mountain rating.

WES-Mobility Terrain Data Bases. Development of mobility-terrain data bases has been supported in part by funds from TRAC to provide realistic mobility input to the CARMONETTE Model for wargaming. The data bases are generally referenced to groups of 1:50,000 topographic line maps. The data are at 100 meter resolution and represent those terrain factors and seasonal conditions that influence vehicle performance. Five major DTD features have been developed for CARMONETTE/CASTFOREM: road code, tree heights, CCM code, elevation, and vehicle speeds. These five features are derived from the digital terrain data base which is composed of many factors, a few of which are soil types, slope, urban code, surface roughness, vegetation spacing, road codes, bridge codes, tunnel codes, river and stream widths, and water-gap bank conditions.

APPENDIX E-3

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APPENDIX E-3

BIBLIOGRAPHY

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ANNEX F

ENGINEER TASK ANALYSIS

ANNEX F

ENGINEER TASK ANALYSIS

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I. INTRODUCTION

1. Purpose. This annex identifies those engineer tasks which should be represented in combat simulations at each level of the AMIP hierarchy.

2. Scope. This analysis is based on:

a. Consolidated, ranked lists of engineer tasks used by ESC to support a series of studies conducted between 1980 and 1987. These ranked lists of engineer tasks represent the opinions of field commanders and their

staffs from theaters throughout the world about the relative importance of individual engineer tasks to success on the battlefield.

b. Person-to-person interviews conducted with members of the modeling and analysis community about how existing models play engineers.

c. An "expert judgement" survey prepared and distributed by ESC which asked modelers, engineer officers, and field commanders to rank engineer tasks under multiple judgement criteria.

3. Limits. In accepting the assignment to formulate a comprehensive plan for improving engineer play in combat simulations, ESC wished to avoid recommending a series of haphazard, expedient fixes to the way engineers are now represented in existing models. Therefore, this analysis began by framing an overall picture of which engineer tasks are most important to the success of the combined arms team on the battlefield. By analyzing the relative importance of engineer tasks in a general philosophical way -- without regard to the capabilities or weaknesses of specific models -- it will be possible to logically and consistently describe the desired level of engineer play in specific models, and then to propose appropriate modifications to those models.

4. Background. ESC has conducted engineer assessments that quantify the requirements for engineer support to combat forces under approved operations plans (OPLANS) for the Combined Forces Command, Korea; the US Army Europe; the Third US Army; the III, V, and VII US Corps; the 9th Infantry Division; and the Light Infantry Division. Each assessment was built around a list of engineer tasks, sorted into priority order by a Study Advisory Group (SAG) comprising representatives of the sponsors' general staff and major subordinate commands. These task lists are key to this analysis, since they represent field commanders' opinions of the type and order of engineer tasks that must be completed to accomplish their OPLAN missions. In addition, the technique of breaking engineer tasks into categories and sorting the categories in priority order is well suited to deciding what engineer tasks are needed in the simulation models established at each level of the AMIP hierarchy.

5. Method. This analysis began by grouping engineer tasks by category, then ranking the categories in terms of the battlefield priority assigned them by field commanders. However, instead of having a SAG work out an approved

list of engineer tasks based on specific OPLAN missions, ESC developed an "expert judgement survey" to get a balanced view of the engineer role on the battlefield under a wide range of combat conditions. In other words, the survey consolidated the need for different types and levels of engineer model play, as expressed by experts from many different disciplines and with different levels of modeling experience.

a. This analysis also grouped engineer tasks into categories using criteria different from the criteria used to develop task lists for the engineer assessments. For the assessments, tasks were broken into categories based on criteria meaningful to tactical planners. For example, to a commander planning a defense, obstacles on the primary avenue of approach would be more important than obstacles on a secondary avenue of approach; therefore, primary-avenue obstacles are put in a separate category from secondary-avenue obstacles. When choosing tasks to represent in a simulation model, however, it does not matter where the tasks occur: generating and locating tasks within the model is a separate problem which is tackled only after it is decided which tasks the model will represent.

b. The Expert Judgement Survey divided engineer tasks into the 16 categories listed in Figure F-1. These categories are based on the way engineer functions will interact with other combat functions in models at different levels, from high-resolution models (battalion/company level) to low-resolution models (theater/army level).

c. Figure F-1 does not cover every function engineers perform on the battlefield, although each category covers a wide variety of engineer activities. A listing of the kinds of tasks included in each category is given as Appendix F-1. However, even if all the tasks implied by categories 1 through 15 are considered candidates for modeling, many engineer functions will still remain unaccounted for. This is intentional -- all models are abstractions of reality. In creating any model, some things must be left out so the model-maker can focus on the functions most important to the intended uses of the model. It is not in the best interests of either the analytic community or the engineers to insist on incorporating all engineer functions into every model which simulates combined arms combat. Even if one ignores both the lengthy development requirements for such an intricate model and the

ENGINEER TASK CATEGORIES DERIVED FROM PAST ESC STUDIES

1. Install linear obstacles (minefields, tank ditches...)
 2. Install point obstacles (road craters, bridge demolition...)
 3. Prepare fighting positions for direct fire systems (tanks, TOWS...),
 4. Prepare positions for indirect fire & other systems (artillery, ADA, CP,...)
 5. Breach obstacles in the assault (breach minefields, span short gaps...)
 6. Improve assault breaches for follow-on forces (clear minefields, widen lanes...)
 7. Conduct river crossing operation in the assault (bank clearing, rafting, assault bridging...)
 8. Improve river crossing site for follow-on forces (fixed bridging, float bridging...)
 9. Maintain main supply routes (fill craters, build up worn shoulders...)
 10. Pioneer trail preparation & maintenance (route clearing, soil stabilization...)
 11. Forward airlanding facility preparation & maintenance (air strip clearing, soil stabilization...)
 12. Site preparation & maintenance for combat support & combat service support units (access road, site clearing...)
 13. Rear area facility rehabilitation & maintenance (building conversion, damage repair...)
 14. Airfield damage repair (crater repair, rubble clearing...)
 15. Port & waterfront facilities construction & repair (pier repair, storage facility rehabilitation...)
 16. Other (While there are many other engineer tasks, respondents were asked to add tasks only if the tasks were vital to model integrity.)
-

Figure F-1

challenge of assembling valid input data, the investments in time and effort to run such a model would make it impractical to use.

d. The key to model building is to represent those functions that have the greatest impact on the phenomenon being modeled. In defining the engineer modeling requirements for the AMIP, ESC tried to exclude engineer tasks that, though important, only *indirectly* affect the outcome of combat simulations. To ensure no critical engineer functions were overlooked, the Expert Judgement Survey included category 16, so the experts surveyed could add engineer tasks they believed must be modeled.

II. DESCRIPTION OF THE EXPERT JUDGEMENT SURVEY

6. Survey Questionnaire. Appendix F-2 to this annex is a copy of the questionnaire ESC used to define and rank the importance of engineer tasks. At the heart of the survey are the 16 engineer task categories listed in Figure F-1. Because the issue of what engineer tasks need to be represented in combat simulations has many different aspects, the survey asks respondents to rank the importance of each task category in terms of several different judgement criteria. The survey also asks respondents to assign weights to the judgement criteria based on how much influence they think each criterion should have in determining each task's final rank. This analysis approach provides an organized way of making decisions about which of many different alternatives is the best, especially when the alternatives have different values under different criteria.

a. The decision process involved in buying a car is the classic example of how this technique is best applied. The buyer ranks each car being considered against different judgement criteria -- cost, reliability, gas mileage. The buyer then weights those judgement criteria based on the importance of each to the overall decision. The rank each car is assigned under each judgement criterion is multiplied by the weight assigned the criterion. The weighted criterion values are added to produce an overall score for each car. The buyer then selects the car which earns the highest score.

b. The strength of this technique is its ability to handle subjective opinions as well as quantitative data. In the car-buying example, the purchaser could make "style" one of the judgement criterion and score each car on its style. Of course, different people will have different opinions about what is "good" or "bad" style, and so different people will rank the same cars differently. But as long as all purchasers use their own ranking system, the technique will work for each of them.

c. Ensuring logical consistency becomes more complicated when the technique is used on a problem that involves organizational rather than personal decisions. In such cases, no one person has a complete perspective, and so no one person can accurately rank all alternatives. Clearly, in the case of deciding what engineer play is needed in Army models, no one person can claim to be the authority. That is why the survey used in this analysis

collected a wide variety of opinions from experts in Army modeling and analysis, engineer functions and doctrine, and operational planning.

7. Survey Respondents. To gain different perspectives on the issue of engineer play in combat simulations, the Expert Judgement Survey was sent to people working in the organizations listed in Figure F-2. ESC also transcribed the ranked engineer tasks lists developed for its eight engineer assessments into the survey format. This was not a straightforward conversion, however. The task list developed by each SAG for each engineer assessment is unique, since it is tailored to a specific OPLAN. The task categories in the Expert Judgement Survey are more general than those used in the engineer assessments. Therefore, the tasks included in each assessment list had to be reaggregated under the survey categories. For example, the Expert Judgement Survey aggregated primary, alternate, and supplementary fighting positions for direct-fire weapons under a single category: prepare fighting positions for direct-fire systems.

ORGANIZATIONS SURVEYED

Department of the Army

Concepts Analysis Agency

US Army Training and Doctrine Command (TRADOC)

US Army Engineer School (USAES)

US Army TRADOC Analysis Command, White Sands Missile
Range (TRAC-WSMR)

US Army TRADOC Analysis Command, Fort Leavenworth
(TRAC-FLVN)

US Army Corps of Engineers (USACE)

Waterways Experiment Station (WES)

Engineer Studies Center (ESC)

Figure F-2

III. ANALYSIS OF SURVEY RESULTS

8. Limits of Survey Results. The Expert Judgement Survey was designed to be very broad and general in scope. The judgement criteria, task categories, and rating scales were all selected to give respondents as much flexibility as possible in the way they chose to fill out the form.

a. Some respondents commented that since they were given so much latitude to interpret the survey in their own way, the final results must necessarily be subject to a great deal of statistical uncertainty. This criticism is absolutely true, but the subjective nature of the problem made it important to maintain a broad perspective, rather than risk missing important aspects of the problem by leading respondents to think in narrower, more limited terms.

b. Since the survey was general in scope, the results must be used only to gain insights into the categories of engineer tasks which must be considered in combat simulations. The ranks assigned engineer tasks as a result of this survey are the foundation from which ESC developed specific recommendations on how to modify existing simulation models to better represent engineer play (see Annexes A through D). However, the task priorities suggested by this survey were not the only basis for determining how the existing models should be modified. Besides the survey rankings, the analyst who examined each model considered the specific scope of that model, how it operates, who uses it, what it is used for, and how engineers are now played by the model.

9. Judgement Criteria.

a. High-, medium-, vs low-resolution. Most respondents considered high-, medium-, and low-resolution models of equal importance in the Army hierarchy of models. Those respondents that assigned different weights, felt the high- and medium-resolution models were more important. The combined respondent scores give the high-resolution models a weight of 40 percent, the medium-resolution models a weight of 32 percent, and the low-resolution models a weight of 28 percent. These statistics indicate a strong consensus that engineer play is important at all three levels.

b. Defense vs offense. Many respondents gave equal weight to the importance of playing engineer support to the defense and to the offense.

This is not unreasonable, since combat models must play both sides of a conflict. Therefore, defense and offense must both be adequately represented. However, since the focus of model analysis is usually on changes that can be made to improve the position of the friendly forces, and since more data are available on friendly forces, models typically represent friendly forces in greater detail than enemy forces. If defense and offense are to be emphasized differently by a model, the most likely posture of the friendly forces should be given the greater weight. Those respondents that assigned different weights gave more importance to engineer play in the defense. The combined scores of all respondents give defense a 61-percent weight and offense a 39-percent weight. These statistics are not surprising, since most model scenarios put US forces in the defense.

c. **Manpower vs equipment.** Only one respondent considered engineer manpower more important than engineer equipment on the battlefield. All other respondents assigned manpower and equipment equal weights, or gave equipment a greater weight. The combined scores of all respondents give engineer equipment a 59-percent weight and engineer manpower a 41-percent weight. These statistics agree with current modeling practice, since even the high-resolution models track equipment (weapon systems) much better than people.

d. **Ease of programming vs data acquisition.** Many respondents said that the effort required to program an engineer task into a model -- or to collect the data input necessary to play the task -- should not be considered in deciding what tasks to model. A typical comment was that the selection of tasks to model "...should be based on battlefield requirements and priorities, not modeling or data considerations." Of the respondents that did give weights to these criteria, about half weighted them equally. The rest weighted ease of data acquisition as more important than ease of programming. The combined scores of all respondents who assigned weights to these criteria give ease of data acquisition a 59-percent weight and ease of programming a 41-percent weight. These statistics show that respondents believe data acquisition is more of a problem than programming. However, it also shows a strong feeling that model modifications should be driven by the criteria that are important to the use of the model, not by the criteria that are important to the *development* of the model.

e. Level of simulation, posture, and resources vs ease of modeling.

When asked to compare the relative importance of the four criteria -- level of simulation, combat posture, engineer resources, and ease of modeling -- ease of modeling was given a low weight by all respondents (zero in many cases). The remaining criteria were all given roughly equal weights. The combined scores of all respondents give level of simulation a weight of 34 percent, combat posture a weight of 30 percent, engineer resources a weight of 29 percent, and ease of modeling a weight of 7 percent. These statistics reinforce the opinion that important model modifications should not be avoided just because a particular function is hard to model.

10. Task Rankings. Each respondent's overall ranking of the engineer tasks included in the Expert Judgement Survey was computed by multiplying each task by the criteria weight assigned by that respondent. This was done to accurately preserve each respondent's opinion. These individual task rankings were combined to produce the overall rankings listed in Figures F-3 through F-5.

a. In its engineer assessments, ESC has found it useful to collect ranked tasks into four groups -- vital tasks, critical tasks, essential tasks, and necessary tasks. These groups further order engineer effort in operational planning. These same groups can be appropriately used to order tasks based on their importance in combat simulations.

b. Respondents were not asked to categorize tasks as vital, critical, essential, or necessary. That aggregation was done by ESC after the survey's overall ranks were computed. However, these groups do seem to fit the natural clustering in the task lists. The clustering is most distinct in the high-resolution ranking (Figure F-3), where only 2.7 percentage points separate the lowest vital task from the highest critical task. The clustering is less pronounced in the medium-resolution ranking (Figure F-4), but is still clear enough to make the groupings unambiguous. The low-resolution ranking (Figure F-5) is much more uniformly distributed, and grouping tasks becomes somewhat arbitrary (particularly deciding the exact dividing line between vital tasks and critical tasks). ESC tested the consistency of these groups by comparing the task rankings of the analytic community (CAA, TRAC, and USACE respondents), the engineer doctrine experts (USAES), and the OPLAN experts (SAGs). For high-resolution models, both the analytic community and the USAES

HIGH-RESOLUTION MODELS -- OVERALL TASK RANKING

Task Categories Sorted in Priority Order	Priority Ranking (%)
<u>Vital Task Group</u>	
Prepare fighting positions for direct-fire systems	12.1
Install linear obstacles	11.1
Breach obstacles in the assault	10.8
Install point obstacles	10.0
Prepare positions for indirect-fire & other systems	9.1
Conduct river crossing operations in the assault	8.4
<u>Critical Task Group</u>	
Improve assault breaches for follow-on forces	5.7
Maintain main supply routes	5.7
Pioneer trail preparation & maintenance	5.3
Improve river crossing sites for follow-on forces	4.9
Forward airlanding facility preparation & maintenance	4.7
Site preparation & maintenance for CS & CSS units	4.5
<u>Essential Task Group</u>	
Rear area facility rehabilitation & maintenance	2.5
Airfield damage repair	2.2
<u>Necessary Task Group</u>	
Other (engineer raids)	1.6
Port & waterfront facilities construction & repair	1.0

Figure F-3

MEDIUM-RESOLUTION MODELS -- OVERALL TASK RANKING

Task Categories Sorted in Priority Order	Priority Ranking (%)
<u>Vital Task Group</u>	
Install linear obstacles	10.7
Prepare fighting positions for direct-fire systems	10.7
Prepare positions for indirect fire & other systems	8.8
Breach obstacles in the assault	8.5
Conduct river crossing operations in the assault	7.9
Install point obstacles	7.7
<u>Critical Task Group</u>	
Forward airlanding facility preparation & maintenance	6.7
Maintain main supply routes	6.5
Pioneer trail preparation & maintenance	5.6
Airfield damage repair	5.6
Improve river crossing sites for follow-on forces	5.4
Improve assault breaches for follow-on forces	5.0
Site preparation & maintenance for CS & CSS units	4.8
<u>Essential Task Group</u>	
Rear area facility rehabilitation & maintenance	3.1
<u>Necessary Task Group</u>	
Port & waterfront facilities construction & repair	1.5
Other (engineer raids & nuclear rubble removal)	1.1

Figure F-4

LOW-RESOLUTION MODELS -- OVERALL TASK RANKING

Task Categories Sorted in Priority Order	Priority Ranking (%)
<u>Vital Task Group</u>	
Install linear obstacles	8.9
Prepare fighting positions for direct-fire systems	8.8
Airfield damage repair	8.1
Maintain main supply routes	7.8
Prepare positions for indirect-fire & other systems	6.9
Port & waterfront facilities construction & repair	6.8
Site preparation & maintenance for CS & CSS units	6.7
Breach obstacles in the assault	6.5
Rear area facility rehabilitation & maintenance	6.4
<u>Critical Task Group</u>	
Forward airlanding facility preparation & maintenance	6.1
Conduct river crossing operations in the assault	5.8
Install point obstacles	5.6
Pioneer trail preparation & maintenance	5.5
<u>Essential Task Group</u>	
Improve river crossing sites for follow-on forces	4.7
Improve assault breaches for follow-on forces	4.0
<u>Necessary Task Group</u>	
Other (engineer raids)	1.2

Figure F-5

rank the same six tasks at the top. These six tasks match the task categories grouped under the vital heading by ESC in the overall survey ranking. The SAGs' ranking has four of the same tasks at the top of their list. However, in the SAG list, "maintain main supply routes" and "prepare and maintain pioneer trails" moved up from the critical task group to the vital task group. This shows the importance field commanders place on keeping the lines of communication open.

c. For medium-resolution models, the analytic community and the USAES again ranked the same six tasks at the top. These tasks again matched the vital task group in the overall survey ranking. The SAGs ranked five of the same tasks at the top of their list. The task, "prepare and maintain forward airlanding facilities," moved up from the critical task group to the vital task group in the SAG's list. Again, this reflects the field commanders' concerns with the lines of communication needed to sustain their forces.

d. For low-resolution models, the analytic community gives top ratings to the same nine tasks grouped by ESC under the vital task group. The USAES summary task rankings match except for one task category -- install point obstacles. The SAGs' have five task categories that match. The four that move up on the list are "preparation and maintenance, forward airlanding facilities," "preparation and maintenance, pioneer trails," "install point obstacles," and "conduct river crossing operations in the assault." These differences appear to reflect USAES and SAG interest in forward area operations even in low-resolution models.

e. ESC found similar results in comparing the critical, essential, and necessary task groups to the ranks assigned by the analytic community, USAES, and the SAGs. Except for the respondents' identities (which are protected by the Privacy Act of 1974), all of the survey data are on file at ESC. They are available to anyone interested in doing a more detailed examination of the results.

11. "Other" Engineer Tasks. The Expert Judgement Survey allowed respondents to add tasks under category 16, "Other." Only two "other" tasks were identified. Because of their relatively specialized nature, they placed low in the overall ranking. One of the "other" tasks proposed by a survey respondent was "nuclear rubble removal." This task could be considered as an

extreme special case of main supply route maintenance and damage repair, but an accurate representation would probably require extra model modifications. The other additional task, "engineer raid," was proposed by SAGs during several of ESC's engineer assessments. The SAGs for these assessments planned engineer supported raids as denial missions forward of the FEBA. The effect of such raids could probably be represented in some models using other combat elements, but the model would have to be modified to reflect the unique engineer capabilities needed to execute such missions. Although these tasks did not place high enough in the rankings to rate inclusion in Army models at this time, they do represent unique engineer contributions to the combined arms team that should be analyzed.

IV. CONCLUSIONS AND RECOMMENDATIONS

12. Conclusions. This survey was successful in gathering and consolidating a broad spectrum of opinions on the relative importance of engineer tasks in combat simulations. However, the summary results cannot be interpreted as representing a consensus. Each respondent's answers reflect only his or her own area of expertise. No attempt was made to get respondents to agree. Thus, the survey results provide a general outline of the kinds of engineer tasks that should be represented in combat simulations, without regard to the practical implications of trying to incorporate those tasks in specific models.

a. **Some important engineer tasks are beyond the scope of high-resolution models.** The general list of 16 task categories used in the survey includes tasks that are beyond the scope of current high-resolution models. The duration of the engagement and the size of the battlefield played in high-resolution models make it impractical to represent such tasks as rear area facility rehabilitation and airfield damage repair. The fact that these tasks scored low in the priority ranking gives credibility to the survey ranking process.

b. **Most engineer tasks fall within the scope of medium-resolution models.** The scope of current medium-resolution models comes closest to covering all of the categories of engineer tasks identified by ESC's Expert Judgement Survey. A strong program to improve engineer play in models at this level would have the greatest potential payoff. However, models at this level lack the resolution to analyze changes in individual pieces of equipment and small unit tactics. The respondents to the survey rated improvements to engineer play in high-resolution models as slightly more desirable than improvements in medium-resolution models (high-resolution = 40 percent: medium-resolution = 32 percent).

c. **Some engineer tasks cannot be explicitly represented by low-resolution models.** The design of current low-resolution models is such that the general list of 16 task categories used in the survey includes tasks that cannot be explicitly represented at this level of aggregation. Low-resolution models emphasize rear area operations that cannot be represented at other levels of resolution. Such representation depends on input from other sources

to adequately depict *forward area* combat results. The fact that forward area engineer operations score high in the overall task ranking for low-resolution models shows that the respondents believe these are still important and must be accounted for even at the level of theater-wide analysis. This means that it is not enough to examine only the results provided by low-resolution models alone when evaluating how to improve engineer play in low-resolution models. Instead, the logic and engineer representation of the models whose results feed the low-resolution model must also be evaluated.

13. Recommendation. The results of ESC's Expert Judgement Survey should be used as a general outline from which to develop much more detailed lists of engineer tasks for individual models. Specifically, the overall priorities derived from the survey should be used as one input to the allocation of effort to improve engineer modeling. Other factors to consider are the current status of engineer play in each individual model, the level of representation of other (non-engineer) functions in each model, and the kinds of analysis each model is intended to support.

APPENDIX F-1

ENGINEER TASKS

APPENDIX F-1

ENGINEER TASKS

1. Install Linear Obstacles (for more detail, see FM 5-102).¹
 - a. **Conventional minefields:**
 - (1) Anti-tank mines
 - (2) Anti-personnel mines
 - b. **Scatterable minefields:**
 - (1) Anti-tank mines
 - (2) Anti-personnel mines
 - c. **Anti-tank ditches:**
 - (1) Rectangular
 - (2) Triangular
 - (3) Sidehill cut
 - d. **Other linear obstacles:**
 - (1) Anti-tank wall
 - (2) Concertina and barbed wire
 - (3) Flooding
 - (4) Fire
 - e. **Complex obstacles (the combination of several of the above obstacles at one location).**
2. Install Point Obstacles (for more detail, see FM 5-102).
 - a. **Road craters:**
 - (1) Hasty
 - (2) Deliberate
 - b. **Bridge demolition:**
 - (1) Spans
 - (2) Abutments
 - (3) Support columns

¹Countermobility, Field Manual (FM) 5-102 (Department of the Army, March 1985).

c. **Expedient obstacles:**

- (1) Abatis
- (2) Log cribs, hurdles, and posts
- (3) Rubble
- (4) Junked vehicles and equipment

d. **Preconstructed obstacles:**

- (1) Prechamber shafts for craters
- (2) Beam posts
- (3) Brackets, chambers, and galleries for bridge demolition
- (4) Falling block obstacles

e. **Atomic demolition munitions:**

- (1) Tunnels
- (2) Major highways
- (3) Bridges
- (4) Narrow valley defiles

3. Prepare Fighting Positions for Direct Fire Systems (for more detail, see FM 5-103).²

a. **Individual firing position:**

- (1) Hasty
- (2) Deliberate

b. **Trenches:**

- (1) Crawl trench
- (2) Standard fighting trench

c. **Crew-served weapons:**

- (1) Hasty
- (2) Deliberate

d. **Fighting vehicles:**

- (1) Hasty
- (2) Deliberate

4. Prepare Positions for Indirect Fire and Other Systems for more detail see FM 5-103).

a. **Artillery - parapet**

b. **Air defense artillery - parapet**

²Survivability, FM 5-103 (Department of the Army, June 1985).

- c. **Support vehicles and vans:**
 - (1) Deep-cut
 - (2) Covered deep-cut
 - d. **Unit positions:**
 - (1) Bunkers
 - (2) Shelters
 - (3) Protective walls and revetments
5. Breach Obstacles in the Assault (for more detail see FM 5-101).³
- a. **Minefields:**
 - (1) Detection
 - (2) Bypass
 - (3) Force through
 - (4) Hasty breach
 - (5) Deliberate breach
 - b. **Obstacles other than minefields:**
 - (1) Detection
 - (2) Bypass
 - (3) Force through
 - (4) Hasty breach
 - (5) Deliberate breach
6. Improve Assault Breaches for Follow-on Forces (for more detail, see FM 5-101).
- a. **Minefields:**
 - (1) Proof lanes
 - (2) Widen lanes
 - (3) Mark minefield
 - (4) Minefield clearing
 - b. **Obstacles other than minefields:**
 - (1) Widen lanes
 - (2) Mark lanes
 - (3) Obstacle reduction

³Mobility, FM 5-101 (Department of the Army, January 1985).

7. Conduct River Crossing Operation in the Assault (for more detail, see FM 5-101).

- a. Site reconnaissance
- b. Bypass
- c. Ford
- d. Swim
- e. Raft
- f. Armored vehicle launched bridge (AVLB)

8. Improve River Crossing Site for Follow-On Forces (for more detail, see FM 5-101).

- a. Improve entry, exit, and bottom at ford sites
- b. Recover rafts and AVLBs
- c. Emplace float bridging
- d. Emplace fixed bridging

9. Maintain Main Supply Routes -- includes highways & railroads (for more detail, see FM 5-104).⁴

- a. Route reconnaissance
- b. Road upgrade
- c. Construction
- d. Routine maintenance
- e. War damage repair

10. Pioneer Trail Preparation and Maintenance (for more detail, see FM 5-101).

- a. Route reconnaissance
- b. Construction
- c. Camouflage and deception
- d. Routine maintenance
- e. War damage repair

11. Forward Airlanding Facility Preparation and Maintenance (for more detail, see FM 5-101).

- a. Helicopter landing zones:
 - (1) Site reconnaissance

⁴General Engineering, FM 5-104 (Department of the Army, November 1986).

- (2) Construction
- (3) Camouflage and deception
- (4) Routine maintenance
- (5) War damage repair
- b. **Forward arming and refueling points (FARP):**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Camouflage and deception
 - (4) Routine maintenance
 - (5) War damage repair
- c. **Low altitude parachute extraction system (LAPES):**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Camouflage and deception
 - (4) Routine maintenance
 - (5) War damage repair
- d. **Landing strips:**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Camouflage and deception
 - (4) Routine maintenance
 - (5) War damage repair

12. Site Preparation and Maintenance for CS and CSS Units (for more detail, see FM 5-104).

- a. **Supply and maintenance sites:**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Camouflage and deception
 - (4) Routine maintenance
 - (5) War damage repair
- b. **Ammunition storage sites:**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Camouflage and deception

- (4) Routine maintenance
 - (5) War damage repair
- c. **Petroleum pipelines and storage sites:**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Camouflage and deception
 - (4) Routine maintenance
 - (5) War damage repair
- d. **Medical treatment sites:**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Routine maintenance
 - (4) War damage repair
- e. **Prisoner detainment sites:**
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Routine maintenance
 - (4) War damage repair

13. Rear Area Facility Rehabilitation and Maintenance (for more detail, see FM 5-104).

- a. Facility reconnaissance
- b. Rehabilitation/conversion of existing facilities
- c. Camouflage and deception
- d. Routine maintenance
- e. War damage repair

14. Airfield Damage Repair (for more detail, see FM 5-104).

- a. Reconnaissance/damage assessment
- b. Explosive ordnance disposal (EOD)
- c. Rapid runway repair
- d. Collateral damage repair

15. Port and Waterfront Facilities Construction and Repair (for more detail, see FM 5-104).

- a. **Breakwaters, docks, piers, wharves, quays, moles, and landing stages:**
 - (1) Site/facility reconnaissance
 - (2) Rehabilitation/conversion of existing facilities

- (3) Construction
- (4) Camouflage and deception
- (5) Routine maintenance
- (6) War damage repair
- b. **Roads in the port area:**
 - (1) Route reconnaissance
 - (2) Construction
 - (3) Camouflage and deception
 - (4) Routine maintenance
 - (5) War damage repair
- c. **Railway facilities in the port area:**
 - (1) Facility reconnaissance
 - (2) Rehabilitation/conversion of existing facilities
 - (3) Construction
 - (4) Camouflage and deception
 - (5) Routine maintenance
 - (6) War damage repair
- d. **Storage and marshaling areas:**
 - (1) Site/facility reconnaissance
 - (2) Rehabilitation/conversion of existing facilities
 - (3) Construction
 - (4) Camouflage and deception
 - (5) Routine maintenance
 - (6) War damage repair
- e. **Port utilities:**
 - (1) Utility systems reconnaissance
 - (2) Rehabilitation/conversion of existing facilities
 - (3) Construction
 - (4) Routine maintenance
 - (5) War damage repair
- f. **Tanker unloading facilities:**
 - (1) Site/facility reconnaissance
 - (2) Rehabilitation/conversion of existing facilities
 - (3) Construction
 - (4) Camouflage and deception

- (5) Routine maintenance
 - (6) War damage repair
- g. Port fire fighting facilities:
 - (1) Site/facility reconnaissance
 - (2) Rehabilitation/conversion of existing facilities
 - (3) Construction
 - (4) Routine maintenance
 - (5) War damage repair
- h. Port support buildings and facilities:
 - (1) Site/facility reconnaissance
 - (2) Rehabilitation/conversion of existing facilities
 - (3) Construction
 - (4) Camouflage and deception
 - (5) Routine maintenance
 - (6) War damage repair
- i. Logistics over the shore (LOTS) sites:
 - (1) Site reconnaissance
 - (2) Construction
 - (3) Camouflage and deception
 - (4) Routine maintenance
 - (5) War damage repair
- j. Dredging
- k. Debris clearance
- 16. Other (tasks identified by respondents to the survey).
 - a. Engineer raids
 - b. Nuclear rubble removal

APPENDIX F-2

EXPERT JUDGEMENT SURVEY

EXPERT JUDGEMENT SURVEY TO RANK THE RELATIVE IMPORTANCE OF ENGINEER TASKS IN COMBAT SIMULATIONS

I. INTRODUCTION

1. PURPOSE. This survey will collect the opinions of experienced officers and modelers to help the Engineer Studies Center (ESC) better define what engineer tasks can and should be represented in Army combat simulations. We want to get a wide variety of opinions to make sure we consider all aspects of the problem of characterizing engineer operations on the battlefield.

2. Scope. The survey is organized into two sections.

A. Judgement Criteria. These are factors that must be considered in ranking the importance of engineer tasks. You will be asked to decide how much weight each of the judgement criteria should have in deciding the overall priority of engineer tasks to include in combat simulations. The criteria are:

- (1). LEVEL OF SIMULATION
(HIGH, MEDIUM & LOW RESOLUTION)
- (2). COMBAT POSTURE
(DEFENSE & OFFENSE)
- (3). ENGINEER RESOURCES
(MANPOWER & EQUIPMENT)
- (4). EASE OF MODELING
(EASE OF PROGRAMMING & AVAILABILITY OF INPUT DATA)

B. Engineer Tasks. If you are familiar with past engineer assessments done by ESC based on Corps, Army and Theater OPLANS you will see the same philosophy of grouping engineer tasks into logically related increments was used to develop the categories for this survey. However, the groupings that resulted, while similar, are not the same as those used in OPLAN based assessments. For this survey engineer operations are divided into categories of similar tasks based on the way they interact with other segments in combat simulations. For each of the judgement criteria you will be asked to rank order the categories of engineer tasks based on your opinion of the impact each category has under that criterion. The engineer task categories are:

- (1). INSTALL LINEAR OBSTACLES
(MINEFIELDS, TANK DITCHES,...)
- (2). INSTALL POINT OBSTACLES
(ROAD CRATERS, BRIDGE DEMOLITION,...)
- (3). PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS
(TANKS, TOWS,...)
- (4). PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS
(ARTILLERY, ADA, CPs,...)
- (5). BREACH OBSTACLES IN THE ASSAULT
(BREACH MINEFIELDS. SPAN SHORT GAPS,...)

- (6). IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES
(CLEAR MINEFIELDS, WIDEN LANES,...)
- (7). CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT
(BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)
- (8). IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES
(FIXED BRIDGING, FLOAT BRIDGING,...)
- (9). MAINTAIN MAIN SUPPLY ROUTES
(FILL CRATERS, BUILD UP WORN SHOULDERS,...)
- (10). PIONEER TRAIL PREPARATION & MAINTENANCE
(ROUTE CLEARING, SOIL STABILIZATION,...)
- (11). FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE
(AIR STRIP CLEARING, SOIL STABILIZATION,...)
- (12). SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS
(ACCESS ROAD, SITE CLEARING,...)
- (13). REAR AREA FACILITY REHABILITATION & MAINTENANCE
(BUILDING CONVERSION, DAMAGE REPAIR,...)
- (14). AIRFIELD DAMAGE REPAIR
(CRATER REPAIR, RUBBLE CLEARING,...)
- (15). PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR
(PIER REPAIR, STORAGE FACILITY REHABILITATION,...)
- (16). OTHER (WHILE THERE ARE MANY OTHER ENGINEER TASKS
PLEASE ADD TASKS ONLY IF THEY ARE VITAL TO MODEL)

3. RESPONSES. The number of different judgement criteria and engineer task categories being considered make this a rather long and complicated survey. In the interest of making the best use of your valuable time please answer as thoughtfully as you can the portions of the survey you feel you have a good basis of experience on which to base your answers. But, feel free to skip any portion of the survey where you feel you lack the experience to make good comparisons -- if you have not been involved in writing or using models you need not answer questions about ease of programming; on the other hand, if you are a modeler with no experience in combat engineering you need not answer the questions about combat posture and engineer resources.

Your Name & Grade _____

Your Organization _____

Mail to: U.S. Army. Engineer Studies Center
ATTN: CEESC (Mr. Stephen C. Reynolds)
Casey Building # 2594
Fort Belvoir, Virginia 22060-5583

II. JUDGEMENT CRITERIA

4. LEVEL OF SIMULATION. In the hierarchy of Army models is it more important to play engineer operations in high (battalion/company), medium (corps/division), or low (theater/army) resolution models?

Consider how you would answer that question and then give the percentage of the engineer model improvement effort you think should be devoted to improving engineer play in each of the three levels of simulation. Base your answers on how important you think it is to measure the value of engineers at each level of resolution.

HIGH RESOLUTION	0	10	20	30	40	50	60	70	80	90	100

MEDIUM RESOLUTION	0	10	20	30	40	50	60	70	80	90	100

LOW RESOLUTION	0	10	20	30	40	50	60	70	80	90	100

5. COMBAT POSTURE. In combat simulations is it more important to play engineer support to the defense or the offense?

Consider how you would answer that question and then place a vertical line at the spot on the scale that best reflects your judgement of the relative importance of playing engineers in the defense and the offense. If you put a mark at the far left it means defense should be the only consideration (DEFENSE is 100% and OFFENSE is 0%). If you put a mark in the center it means defense and offense are equally important (DEFENSE is 50% and OFFENSE is 50%). And if you put a mark at the far right it means offense should be the only consideration (OFFENSE is 100% and DEFENSE is 0%).

DEFENSE	100	90	80	70	60	50	40	30	20	10	0

OFFENSE	0	10	20	30	40	50	60	70	80	90	100

6. ENGINEER RESOURCES. In combat simulations is it more important to play engineer manpower or equipment requirements?

Consider how you would answer that question and then place a vertical line at the spot on the scale that best reflects your judgement of the relative importance of playing engineer manpower requirements and engineer equipment requirements. If you put a mark at the far left it means manpower should be the only consideration (MANPOWER is 100% and EQUIPMENT is 0%). If you put a mark in the center it means manpower and equipment are equally important (MANPOWER is 50% and EQUIPMENT is 50%). And if you put a mark at the far right it means equipment should be the only consideration (EQUIPMENT is 100% and MANPOWER is 0%).

MANPOWER	100	90	80	70	60	50	40	30	20	10	0

EQUIPMENT	0	10	20	30	40	50	60	70	80	90	100

7. EASE OF MODELING. In combat simulations is it better to add engineer tasks that are easy to program or tasks for which data is easy to acquire?

Consider how you would answer that question and then place a vertical line at the spot on the scale that best reflects your judgement of the relative importance of choosing engineer tasks to add to simulations based on how easily they can be programmed or how easily the input data can be acquired. If you put a mark at the far left it means ease of programming should be the only consideration (PROGRAMMING is 100% and DATA is 0%). If you put a mark in the center it means programming and data acquisition are equally important (PROGRAMMING is 50% and DATA is 50%). And if you put a mark at the far right it means data acquisition should be the only consideration (DATA is 100% and PROGRAMMING is 0%).

PROGRAMMING	100	90	80	70	60	50	40	30	20	10	0

DATA	0	10	20	30	40	50	60	70	80	90	100

8. CRITERIA WEIGHTING. You have rated the relative importance of the categories within each of the four judgement criteria (level of simulation, combat posture, engineer resources and ease of modeling). Now it is necessary to decide the relative importance of the judgement criteria themselves.

In developing the plan to prioritize engineer model improvement efforts how much weight should each of the judgement criteria have on the decision?

Consider your answer to that question and then place a vertical line at the spot on each scale that best reflects your judgement of the relative importance of the four criteria.

LEVEL OF SIMULATION	0	10	20	30	40	50	60	70	80	90	100

COMBAT POSTURE	0	10	20	30	40	50	60	70	80	90	100

ENGINEER RESOURCES	0	10	20	30	40	50	60	70	80	90	100

EASE OF MODELING	0	10	20	30	40	50	60	70	80	90	100

III. ENGINEER TASKS

COMBAT POSTURE -- IN HIGH RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THEIR IMPORTANCE IN BATTALION/COMPANY LEVEL MODELS

RATE THE IMPORTANCE OF EACH CATEGORY ON A SCALE FROM 1 TO 100 (MOST IMPORTANT = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>IMPORTANCE IN DEFENSE</u>	<u>IMPORTANCE IN OFFENSE</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	REAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADR	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, RUBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

COMBAT POSTURE -- IN MEDIUM RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THEIR IMPORTANCE IN CORPS/DIVISION LEVEL MODELS

RATE THE IMPORTANCE OF EACH CATEGORY ON A SCALE FROM 1 TO 100 (MOST IMPORTANT = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>IMPORTANCE IN DEFENSE</u>	<u>IMPORTANCE IN OFFENSE</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	REAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADR	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, RUBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

COMBAT POSTURE -- IN LOW RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THEIR IMPORTANCE IN THEATER/ARMY LEVEL MODELS

RATE THE IMPORTANCE OF EACH CATEGORY ON A SCALE FROM 1 TO 100 (MOST IMPORTANT = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>IMPORTANCE IN DEFENSE</u>	<u>IMPORTANCE IN OFFENSE</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	REAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADP	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, PEBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

ENGINEER RESOURCES -- IN HIGH RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THE AMOUNT OF ENGINEER RESOURCES THEY REQUIRE
IN BATTALION/COMPANY LEVEL MODELS

RATE THE AMOUNT OF RESOURCES REQUIRED IN EACH CATEGORY ON A SCALE FROM 1 TO 100 (MOST RESOURCES = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>AMOUNT OF MANPOWER</u>	<u>AMOUNT OF EQUIPMENT</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	REAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADR	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, RUBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

ENGINEER RESOURCES -- IN MEDIUM RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THE AMOUNT OF ENGINEER RESOURCES THEY REQUIRE
IN CORPS/DIVISION LEVEL MODELS

RATE THE AMOUNT OF RESOURCES REQUIRED IN EACH CATEGORY ON A SCALE FROM 1 TO 100 (MOST RESOURCES = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>AMOUNT OF MANPOWER</u>	<u>AMOUNT OF EQUIPMENT</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	PEAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADR	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, RUBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

ENGINEER RESOURCES -- IN LOW RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THE AMOUNT OF ENGINEER RESOURCES THEY REQUIRE
IN THEATER/ARMY LEVEL MODELS

RATE THE AMOUNT OF RESOURCES REQUIRED IN EACH CATEGORY ON A SCALE FROM 1 TO 100 (MOST RESOURCES = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>AMOUNT OF MANPOWER</u>	<u>AMOUNT OF EQUIPMENT</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	REAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADR	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, RUBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

EASE OF MODELING -- IN HIGH RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THE EASE OF MODELING THEM IN BATTALION/COMPANY LEVEL MODELS

RATE THE EASE OF MODELING OF EACH CATEGORY ON A SCALE FROM 1 TO 100 (EASIEST = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>EASE OF PROGRAMMING</u>	<u>AVAILABILITY OF DATA</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	REAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADR	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, RUBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

EASE OF MODELING -- IN LOW RESOLUTION SIMULATIONS

SCORE THE CATEGORIES OF ENGINEER TASKS BASED ON
THE EASE OF MODELING THEM IN THEATER/ARMY LEVEL MODELS

RATE THE EASE OF MODELING OF EACH CATEGORY ON A SCALE FROM 1 TO 100 (EASIEST = 100)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>EASE OF PROGRAMMING</u>	<u>AVAILABILITY OF DATA</u>
1. OBST-LN	INSTALL LINEAR OBSTACLES (MINEFIELDS, TANK DITCHES,...)	_____	_____
2. OBST-PT	INSTALL POINT OBSTACLES (ROAD CRATERS, BRIDGE DEMOLITION,...)	_____	_____
3. POS-DIR	PREPARE FIGHTING POSITIONS FOR DIRECT FIRE SYSTEMS (TANKS, TOWS,...)	_____	_____
4. POS-IND	PREPARE POSITIONS FOR INDIRECT FIRE & OTHER SYSTEMS (ARTILLERY, ADA, CPs,...)	_____	_____
5. BREACH-AS	BREACH OBSTACLES IN THE ASSAULT (BREACH MINEFIELDS, SPAN SHORT GAPS,...)	_____	_____
6. BREACH-IM	IMPROVE ASSAULT BREACHES FOR FOLLOW-ON FORCES (CLEAR MINEFIELDS, WIDEN LANES,...)	_____	_____
7. RIVER-AS	CONDUCT RIVER CROSSING OPERATION IN THE ASSAULT (BANK CLEARING, RAFTING, ASSAULT BRIDGING,...)	_____	_____
8. RIVER-IM	IMPROVE RIVER CROSSING SITE FOR FOLLOW-ON FORCES (FIXED BRIDGING, FLOAT BRIDGING,...)	_____	_____
9. MSR-MAINT	MAINTAIN MAIN SUPPLY ROUTES (FILL CRATERS, BUILD UP WORN SHOULDERS,...)	_____	_____
10. TRAIL-WRK	PIONEER TRAIL PREPARATION & MAINTENANCE (ROUTE CLEARING, SOIL STABILIZATION,...)	_____	_____
11. FWD-AFLD	FORWARD AIRLANDING FACILITY PREPARATION & MAINTENANCE (AIR STRIP CLEARING, SOIL STABILIZATION,...)	_____	_____
12. SITE-PREP	SITE PREPARATION & MAINTENANCE FOR CS & CSS UNITS (ACCESS ROAD, SITE CLEARING,...)	_____	_____
13. FACILITY	REAR AREA FACILITY REHABILITATION & MAINTENANCE (BUILDING CONVERSION, DAMAGE REPAIR,...)	_____	_____
14. ADR	AIRFIELD DAMAGE REPAIR (CRATER REPAIR, RUBBLE CLEARING,...)	_____	_____
15. PORT-WRK	PORT & WATERFRONT FACILITIES CONSTRUCTION & REPAIR (PIER REPAIR, STORAGE FACILITY REHABILITATION,...)	_____	_____
16. OTHER	DESCRIBE: _____ (ADD TASKS ONLY IF YOU FEEL THEY ARE VITAL TO MODEL)	_____	_____

LAST PAGE OF APPENDIX F-2

ANNEX G

MISSIONS AND FUNCTIONS STATEMENT



DEPARTMENT OF THE ARMY

TRADOC ANALYSIS CENTER
FORT LEAVENWORTH, KANSAS 66027-6200

12 June 1986

REPLY TO
ATTENTION OF

MEMORANDUM OF UNDERSTANDING BETWEEN THE ENGINEER STUDIES CENTER AND THE TRADOC ANALYSIS CENTER

SUBJECT: Engineer Studies Center (ESC) Officer with Duty Station at TRADOC Analysis Center (TRAC)

1. The purpose of this memorandum is to outline the mission, functions, and operating procedures associated with assigning an ESC officer to the TRAC technical staff.

2. Background.

a. During October and November of 1985, a series of messages were sent by USAES, USACE, and Fort Leavenworth, all in reference to engineer staffing at TRAC. As a result, one initiative proposed by USACE was the assignment of an engineer officer to ESC, with duty station at TRAC. Following CAORA's concurrence, an ODP authorization was moved by HQ USACE to ESC. The first ESC officer to be located at TRAC has also been identified (LTC George R. Meador, Cdr, 14th Engr Bn). The projected reporting date for LTC Meador is August 1986.

b. The primary objective of this action is to assist TRAC in determining and modeling the value of engineers as members of the combined arms team. A secondary objective is to determine and model the importance of engineers in their combat support and combat service support roles. This will be done by improving the modeling of engineers within the entire hierarchy of Army models.

3. General Agreement. It is the collective belief of TRAC, USAES, and USACE that an officer assigned to ESC with duty at TRAC can be made to work. The officer will be given the charter of working 50 percent of the time in direct support of TRAC and working the remaining 50 percent on achieving the Chief of Engineer's goal of improving the representation of engineers within the hierarchy of Army models.

a. The TRAC work will include:

(1) Providing direct engineer expertise in scenario development by highlighting engineer missions, establishing engineer requirements, and determining engineer capabilities.

(2) Maintaining close coordination with USAES to ensure that the latest engineer doctrine/concepts are considered in the TRAC simulations and studies.

(3) Calling on USAES is needed to ensure that the necessary engineer staff is provided to support TRAC requirements, i.e., gamers/players.

SUBJECT: Engineer Studies Center (ESC) Officer with Duty Station at TRADOC
Analysis Center (TRAC)

(4) In general, being responsible for seeing that all TRAC activities include adequate consideration of engineers.

b. The USACE work would include:

(1) Calling on the expertise available within ESC to improve engineer modeling (does not include computer programming).

(2) Being the TRAC/USACE interface for all actions taken by USACE Field Operating Agencies in engineer modeling.

(3) Coordinating USAES needs in modeling of engineers.

(4) Working toward the integration of engineer play/activities in all levels of the hierarchy of Army models and fulfilling the goals of the Army Model Improvement Program.

c. Implied within this action is the recently assigned responsibility of ESC as the center of competence for engineer modeling within the Army. As such, ESC has been charged with the mission of furthering the Chief of Engineers desires to improve the modeling of engineers. In this role, ESC will have the responsibility for initiating, coordinating, and integrating all engineer modeling within the direct linkage models that make up the hierarchy of Army models.

4. Administrative Agreement.

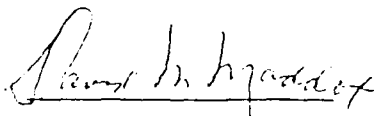
a. Although the officer will technically be assigned to ESC, Fort Leavenworth will provide all of the administrative and logistics support normally provided to an officer of equal rank assigned to TRAC.

b. Since the officer is technically assigned to ESC, the Commander/Director of ESC will be the rating officer. The CG TRAC will be the intermediate rater and the CG USAES will be the senior rater.

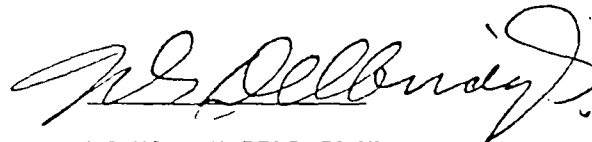
5. This memorandum of understanding is formally agreed to by:



MG R. S. KEM
Commandant, USAES



BG DAVID M. MADDOX
DCG, TRAC



MG NORMAN DELBRIDGE
DCG, USACE



DEPARTMENT OF THE ARMY

U.S. Army Corps of Engineers
WASHINGTON, D.C. 20314

REPLY TO
ATTENTION OF:

3 DEC 1966

ESC-EO

SUBJECT: Engineer Studies Center's Role in Engineer Modeling

Deputy Chief of Staff for Operations
and Plans

ATTN: DAMO Pentagon
Washington, DC 20310

1. I consider the proper representation of engineers within the Army's Combat Models to be of great importance to both US Army Corps of Engineers and the Total Army. Such representation requires integrating all aspects of the engineer functional models interfacing with the Army Model Improvement Program (AMIP). To further these goals, I have designated the Engineer Studies Center (ESC) as the Center of Engineer Modeling for USACE and the USACE point of contact for AMIP.

2. In fulfilling this mission, ESC will:

a. Monitor and evaluate the representation of engineers within the hierarchy of Army models and provide, in coordination with the US Army Engineer School (USAES), recommendations to the Army Models Committee.

b. Provide primary USACE interface with the AMIP Management Office (AMMO) and other AMIP participating organizations on matters relating to Engineer Modeling.

c. Serve as the USACE point of contact with the ARSTAFF on all matters pertaining to AMIP Engineer Modeling.

d. Serve as USACE program manager for AMIP Engineer Model improvements provided by USACE laboratories.

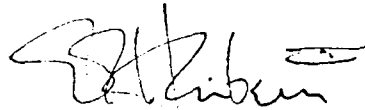
3. The designation of ESC as the Center of Engineer Modeling within USACE is intended to strengthen the engineer community's involvement in modeling. This designation does not circumvent the duties and responsibilities of

DEC 1966

ESC-AO

SUBJECT: Engineer Studies Center's Role in Engineer Modeling

the USAES as the Engineer Proponent with its prescribed responsibilities under TRADOC for modeling. ESC's AMIP work and modeling initiatives will be fully coordinated with, and concurred in, by the USAES.



E. R. HEIBERG III
Lieutenant General, USA
Commanding

CF:

DUSA(OR)

DAS

ANNEX H

BIBLIOGRAPHY

ANNEX H

BIBLIOGRAPHY

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LAST PAGE OF ANNEX H

ANNEX I
STUDY REVIEW COMMENTS

ANNEX I
STUDY REVIEW COMMENTS

<u>Paragraph</u>	<u>Page</u>
1 Purpose	I-1
2 Scope	I-1
3 Disposition of Comments	I-1

1. Purpose. At the completion of the study, ESC published a draft version of this report that was distributed for review and comment. This annex lists those comments and ESC's responses (when required).

2. Scope. This annex presents the comments that ESC received from a select group of agencies interested in the study. It not only lists the comments received, but presents responses by ESC to substantive remarks (i.e., non-editorial comments). Changes have been made to the report when called for, and are indicated as such. Many comments, though pertinent, have not resulted in any changes to the report, and are discussed in this annex only.

3. Disposition of Comments. This paragraph presents the comments and responses. The general format will be to list the comment and the organization making it, followed by ESC's response and reaction .

a. COMMENT (Submitted by Ops Analysis Group, ROK/US CFC): While engineer representation in the models we use here is of concern, there is equal concern about how other functions are represented (i.e., chemical, medical, transportation, C³I, helicopter, etc.). And of even more concern is the representation of Joint/Combined Forces and Special Operations Forces. Our efforts to improve our models have generally followed a modular approach. Our version of MTM, for example, actually consists of about 300 integrated programs (215,000 lines of code). It is hoped that as the EMIP progresses, that the code/logic, etc., will be exportable to other models -- the interactive ones that are used for training/exercises. Despite the PR, JTLS, JESS, etc., leave much to be desired.

ESC RESPONSE: ESC developed this plan as a near-term fix to the most critical problems (i.e., the automated AMIP models). Once EMIP is underway, ESC will refocus its attention to the interactive analytical and

training simulations. We believe that improvements to the fully automated models, when completed and approved, can be transferred fairly easily to these other models.

b. COMMENT (Submitted by Ops Analysis Group, ROK/US, CFC): Reading through the report (Main Paper), when Digitized Terrain discussion popped up, it seemed out of place or an after-thought. On reading Annex E, particularly the Conclusions on pages E-26 and E-27, I could not see a basis for the strong recommendations and conclusions of the Main Paper. Suggest DTD be eliminated or be included as a separate monograph.

ESC RESPONSE: ESC recognizes the Army's DTD requirements encompass far more than the EMIP and has modified the main paper to clarify this position. Although Annex E will not be dropped, ESC plans to publish a separate monograph on this topic.

c. COMMENT (Submitted by Ops Analysis Group, ROK/US, CFC): Page A-12, last sentence has something left out -- appears to have no continuity to page A-13.

ESC RESPONSE: Corrected.

d. COMMENT (Submitted by Ops Analysis Group, ROK/US, CFC): Page C-2, last sentence has something left out -- appears to have no continuity to page C-3.

ESC RESPONSE: Corrected.

e. COMMENT (Submitted by Ops Analysis Group, ROK/US, CFC): Page C-24, line 11 -- "Management" should read "Model."

ESC RESPONSE: Corrected.

f. COMMENT (Submitted by Ops Analysis Group, ROK/US, CFC): Page A-22, 5th line from bottom -- "addition" should be "additional."

ESC RESPONSE: Corrected.

g. COMMENT (Submitted by Plans and Programs Office, CERL): ANNEX B (VIC). The enhancements to VIC outlined in the four phases in this annex will improve the engineer representation of this AMIP model significantly. In the

detailed design of these enhancements, however, the developers cannot lose sight of the purpose of the model as outlined on page B-7. The improvements in the engineer representation must be consistent with the model's level of detail and purpose. ESC must provide specific guidance on the level of detail desired. The authors of this plan identify four very important deficiencies in previous Army combat models: poor documentation, poor response to study needs, inconsistent results, and differing data assumptions. The EMIP plan, however, does not take the actions necessary to prevent the same deficiencies in VIC/EFAM:

(1) Funds are not allotted for documentation. Page B-47 (2) clearly states that the funding for the phased improvements of VIC is for programming effort alone and specifically excludes documentation. Yet (3) of that same page states that documentation by the programming agency is required.

(2) All of the VIC phase descriptions underestimate the requirements for guidance on concepts and doctrine. The doctrinal implications of coding assumptions must be monitored by a subject matter expert (SME) at each stage of development so that the code has credibility from the very beginning. ESC must establish a structure for coordinating the efforts.

(3) Testing and validation of the code are essential to ensure credible output. Funds are not allocated for this task. In addition, validation of the code should be done by an agency which is independent of the code developers.

Because of the very tight development schedule for VIC/EFAM, the timing of the preparation of the tactical decision rules (TDR) is crucial. This is mentioned on page B-41 as a part of Phase Two, but TDRs must be developed for tasks in Phases Three and Four as well.

Phase One task G3 (Figure B-12) must be an ongoing implementation, with the effects of night/weather/smoke on engineer task performance integrated with the development of the coding for each of the engineer tasks.

In Phase Two (Figure B-13), only degrading and damaging of existing MSRs can be implemented for G8 since general road use will not be coded until Phase Four.

ESC RESPONSE: Comments noted. Overall revised cost estimates are contained in the main report. ESC will assure that the appropriate level of guidance and management is available.

h. COMMENT (Submitted by Plans and Programs Office, CERL): ANNEX C (FORCEM). The time schedule for the completion of work on FORCEM is too short. We estimate that the Concepts Analysis Agency (CAA) will need two years to complete its work. During that time, the engineer community must keep abreast of changes to ensure that the model design will support future engineer enhancements.

ESC RESPONSE: A revised FORCEM schedule is contained in the main report.

i. COMMENT (Submitted by Plans and Programs Office, CERL): ANNEX D (EFAM). In the discussion of the three alternatives for developing an EFAM, two problems arise when VIC is used as the combat generator. Alternative 2 states that an EFAM based on VIC will be difficult for the USAES to operate and maintain. Alternative 3 states that VIC does not have the terrain resolution to play engineers in detail.

VIC is an unwieldy, data-intensive model requiring sophisticated hardware and a large support staff, neither of which is currently available to USAES. This problem needs to be addressed early in the development states of the EMIP program. The poor terrain resolution of the current version of VIC is as much a problem for Alternative 2 as it is for Alternative 3. In order to play engineers at all, VIC's terrain representation and movement algorithms must be improved, even at the cost of run time increases.

ESC RESPONSE: The combined EFAM-VIC program will address this problem.

j COMMENT (Submitted by Plans and Programs Office CERL): ANNEX E (DIGITAL TERRAIN DATA IN SUPPORT OF LAND COMBAT MODELS). While this chapter deals with the difficulty of obtaining detailed terrain data, the use of that data in modeling more realistic movement of units is not mentioned. The resolution of the effects is as important as the resolution of the data.

For example, in the present version of VIC, the size of a grid square, the number of levels of elevation, and the number of types of ground cover are not limited, but the trafficability level determined by combinations of elevation, ground cover, and weather can be only one of three values: good, fair, or poor. Clearly, increasing the level of detail in the terrain data will yield a more realistic modeling of movement only if there is a corresponding increase in the level of detail of resulting effects. This study needs to recognize the importance of linking what is known about the environment with factors such as movement speed and line of sight which are influenced by that environment.

ESC RESPONSE: Annex E was written to highlight the serious problem the Army has with obtaining digital terrain data coverage to support the needs of both combat models and weapon systems. ESC's analysis of the changes needed in how specific models represent movement effects are addressed in annexes A through D.

k. COMMENT (Submitted by Plans and Programs Office, CERL): Page 25: EFAM Phase One includes "resolution to an individual piece of engineering equipment." This capability will be in place after Phase One changes to VIC.

ESC RESPONSE: Corrected.

l. COMMENT (Submitted by Plans and Programs Office, CERL): Page B-7: VIC statistics should be 150,000 lines of code (12 million bytes) and nearly one million bytes of data.

ESC RESPONSE: The paragraph has been revised.

m. COMMENT (Submitted by Plans and Programs Office, CERL): Figure B-7 and (1) on page B-27: The present version of VIC does not allow dynamic request for engineer-emplaced minefields.

ESC RESPONSE: The paragraph has been revised.

n. COMMENT (Submitted by Plans and Programs Office, CERL): Page B-35: VIC does model survivability from indirect fire using the same defensive preparation level used for direct fire.

ESC RESPONSE: The paragraph has been revised.

o. COMMENT (Submitted by TRAC-FLVN): Task G7, "Add Capability for maneuver units to use roads," is listed to begin planning in Phase I, but be completed in a later phase. The priority of this task needs elevated substantially due to the possible methodology effects in areas such as CM3, M1, and M5 ("Add capability for dynamic site selections and emplacements," "Add dynamic capability for engineer units to breach minefields," and "Add dynamic request and capability for engineer units to breach linear obstacles"). The planning for G7 needs to be done in advance of these tasks to ensure that the proper data structures and methodologies are employed.

ESC RESPONSE: Comment noted.

p. COMMENT (Submitted by TRAC-FLVN): While TRAC-FLVN agrees that sharing the cost of development of the EMIP Plan amongst the various agencies listed on page 31 is a desirable goal, this agreement does not imply that TRAC has either the funding or personnel to assist with this effort. The one manyear and \$120,000 per year cost share to TRAC for each of FY88 and FY89 cannot be allocated by TRAC-FLVN. TRAC-WSMR must be the resource for this CASTFOREM effort via the AR 5-5 process.

ESC RESPONSE: Comment noted.

q. COMMENT (Submitted by AMSAA): A general recommendation that applies to at least the VIC and FORCEM engineer representation enhancements is that, parallel to the effort to improve the scope and depth of engineer representation in these major analytic models, the ESC develop a more abstract, faster-running version for incorporation in both models when the analysis being performed does not pertain to decisions on engineer assets. Despite the on-going efforts to improve run time (including a current AMSAA task to adapt VIC to Cray computers), there will remain a need for much more responsive models than we now have. This recommendation is somewhat analogous to combining the EMIP alternatives 2 and 3, page D-7.

ESC RESPONSE: ESC agrees with this recommendation. One goal of the EMIP will be to continuously seek ways to improve the responsiveness of the models.

r. COMMENT (Submitted by AMSAA): It is suggested that the total engineer countermeasure effort will be inadequately represented if the modeling accounts only for requests by maneuver unit (e.g., page B-33, para (3)(a)). Signal, medical, logistics, headquarters and other elements will need frequent and responsive engineer assistance when they encounter Red FASCAM.

ESC RESPONSE: The paragraph has been revised.

s. COMMENT (Submitted by Director, FORCEM Task Force): Page 15, Para 12a, Line 9. CAA has recently launched an effort to emphasize and accelerate continued FORCEM model development which had suffered at the expense of study support activities for some time. As a part of this, program model study support will be curtailed by CY 88, and FORCEM will not be used in support of the OMNIBUS-89 study.

ESC RESPONSE: Changes have been made to reflect this development.

t. COMMENT (Submitted by Director, FORCEM Task Force): Page 18, Para 15a(3)(c), line 3. Suggest rewording to read "will remain to be addressed" rather than "...is likely to remain unaddressed."

ESC RESPONSE: Paragraph has been revised.

u. COMMENT (Submitted by Director, FORCEM Task Force): Page C-5, Para 5, line 6. A Model Output document also exists, put out at the same time as the Model Data Input document.

ESC RESPONSE: The paragraph has been revised.

v. COMMENT (Submitted by Director, FORCEM Task Force): Page C-5, Para 6, Line 4. Computer description should read "1100/84 computer having 4 megawords..."

ESC RESPONSE: The paragraph has been revised.

w. COMMENT (Submitted by Director, FORCEM Task Force): Page C-7, Top of Page, 2d Line. The procedure for collecting VIC data to support a linkage with FORCEM similar to the present COSAGE - FORCEM linkage has been worked out. The programs to implement this should be completed this FY.

ESC RESPONSE: Text has been updated.

x. COMMENT (Submitted by Director, FORCEM Task Force): Page C-7, Para 6c(2), Line 10. Considerable analysis and some preliminary study work have been done on the question of a requirements mode of operation for FORCEM. However, an operational capability which would do away with FASTALS is not likely in the next year.

ESC RESPONSE: Text revised to show that this has been considered, but not solved.

y. COMMENT (Submitted by Director, FORCEM Task Force): Page C-7, Para 7a, Line 2. Arrival of units and supplies in the theater are two other, and more important, external events.

ESC RESPONSE: Units and supply arrivals were implicit in the arrivals' reference.

z. COMMENT (Submitted by Director, FORCEM Task Force): Page C-9, Para 7c, Line 9. The present placement of engineer operations as a component module of CSS operations is a matter of FORCEM logical program structure, and not a statement about the significance of engineer operations. It is a separate module which could be invoked independently of CSS.

ESC RESPONSE: Text has been revised to remove connotation of deliberate slighting of engineers.

aa. COMMENT (Submitted by Director, FORCEM Task Force): Page C-9, Para 8, Line 9. Sentence beginning "FORCEM has relied on units..." is confusingly worded. Recommend something like, "Only units may be detected and attacked." (Work is planned to change both the unit data structure and target representation.)

ESC RESPONSE: Text has been changed to clearer statements.

bb. COMMENT (Submitted by Director, FORCEM Task Force): Page C-10, Figure C-3. Intelligence, communication and engineer units are also present at all levels. ATAF (Allied Tactical Air Force) units exist at the theater level. Airbases are not at division level. They may be located anywhere but are subordinate to ATAF units at theater level. Explicit convoys do not operate from the division level, only from corps and higher levels. Task Force)

ESC RESPONSE: Figure changed with corrections added.

cc. COMMENT (Submitted by Director, FORCEM Task Force): Page C-10, last 2 sentences. Terrain effects on engagement are represented indirectly, if very imperfectly, through the division level sample.

ESC RESPONSE: COSAGE terrain considerations are now mentioned.

dd. COMMENT (Submitted by Director, FORCEM Task Force): Page C-14, Para 11, Line 6. Recommend deletion of parenthetical comment on CEM.

ESC RESPONSE: Agree.

ee. COMMENT (Submitted by Director, FORCEM Task Force): Page C-17, Para 12b, Line 1. The term "ignoring" conveys a sense of deliberateness. The reason for absence of engineer representation is not because the issue was ignored. The whole paragraph sounds a little didactic.

ESC RESPONSE: ESC has changed some of the wording, but believes it must assume an advocacy role to ensure just engineer representation.

ff. COMMENT (Submitted by Director, FORCEM Task Force): Page C-18, Para 12b(3), Line 20. Is this a strawman; is anyone making this argument? This sentence, and the one preceding, could easily be dropped.

ESC RESPONSE: This may have been anticipating defenses that have been used before by others. In any case, the language has been changed.

gg. COMMENT (Submitted by Director, FORCEM Task Force): Page C-20, Para 13a(2), Line 15. Such measures of installation size (and capability) as number of beds or troops are used for support command units, which are not

mentioned here, though they are in the same category. The point that physical installation facilities are not represented is correct.

ESC RESPONSE: Comment noted.

hh. COMMENT (Submitted by Director, FORCEM Task Force): Page C-22, Para 13a(3)(a), Line 6. VIC is now operational on the VAX 8600 at CAA. A VIC familiarization study is just being completed and a COSAGE-VIC comparison study is just starting. Results of this study will help determine the schedule for transition from COSAGE to VIC.

ESC RESPONSE: Text changed to reflect new situation.

ii. COMMENT (Submitted by Director, FORCEM Task Force): Page C-26, Para 13b(2). This paragraph presents suggestions for FORCEM modeling changes not directly concerned with engineer representation. The comments reflect changes already planned by CAA for reasons having nothing to do with engineers. While such comments are not unwelcome, they seem extraneous to this review.

ESC RESPONSE: Since the "unit" was the undoing of earlier engineer modeling, ESC sought only to make a case for flexibility and side benefits.

jj. COMMENT (Submitted by Director, FORCEM Task Force): Page C-30, Para 14a, Line 3. The question of how to deal with requirements analysis in FORCEM has been addressed, though not solved. The issue has not been addressed with respect to engineers, however.

ESC RESPONSE: Text changed to indicate that problem has been addressed.

kk. COMMENT (Submitted by Director, FORCEM Task Force): Page C-31, Para 14e. This paragraph and the two following present comments about modeling which are generally correct, but seem to be outside the scope of this review. More specific points related to the anticipated tasks would be better.

ESC RESPONSE: Although some rewording has been made, ESC still feels compelled to caution designers and users about logic and data clarity.

ll. COMMENT (Submitted by Director, FORCEM Task Force): Page C-31, Para 14f. The meaning of this paragraph (or its title) is not clear.

ESC RESPONSE: If FORCEM only represents a portion of engineer tasks, then interpretation and impact on force structure should recognize that some tasks and units are not reflected.

mm. COMMENT (Submitted by Director, FORCEM Task Force): Page C-32, Para 15. Comments about the shortcomings of SIMSCRIPT are interesting, but again seem somewhat off the subject.

ESC RESPONSE: Comments are intended to illustrate that FORCEM can not "protect" or "hide" a submodule.

nn. COMMENT (Submitted by Director, FORCEM Task Force): Page C-33, Para 18, Line 6. This comment about recovery operations and convoys seems gratuitous.

ESC RESPONSE: Comment shows engineer frustration with frequently being "not represented." A more direct statement to this effect has been substituted.

oo. COMMENT (Submitted by Director, FORCEM Task Force): Page E-23, Para 14a, Line 13. FORCEM digitized terrain also exists for Korea and Southwest Asia, but has never been used or fully tested with the model.

ESC RESPONSE: The paragraph has been revised.

pp. COMMENT (Submitted by Director, FORCEM Task Force): Page E-24, Para 14c(1)(a), Line 10. POL pipelines are not necessarily assumed. They may be "turned off" by input.

ESC RESPONSE: The paragraph has been revised.

qq. COMMENT (Submitted by Assistant Chief of Engineers): I believe the plan is on target with the recommendation that we must focus our efforts on the Vector in Commander (VIC) model. Upgrading the engineer representation in this mid-range model will give us the greatest possible return for our efforts. Most of the plan's recommended changes are realistic and reasonable. It is essential that we make these changes as quickly as possible. If the

changes are delayed too long, we increase the risk that VIC will be replaced or changed before our ideas can be implemented.

ESC RESPONSE: Agree.

rr. COMMENT (Submitted by Assistant Chief of Engineers): The EMIP Plan outlines the need to improve the US Army engineer representation in the US Army's models. The threat engineer representation must be similarly improved. If the threat engineer forces are not accurately portrayed, the model will not be improved. These tasks should be explicitly discussed in the plan because we need to maintain balance in the models while accurately representing the capabilities of both forces.

ESC RESPONSE: The EMIP Plan does not differentiate between red and blue engineer representation. Representation of the threat will be given a balanced treatment.

ss. COMMENT (Submitted by Assistant Chief of Engineers): The EMIP Plan recommends ETL produce the digitized terrain data (DTD) needed to improve the terrain representation in the Army models. This is a major additional effort for ETL which is already stretched thin. The plan estimates that this new work will require about 20 people and \$3 to \$5 million. In light of the austere years that we face, I am not sure that these expectations are reasonable.

ESC RESPONSE: Out of a recognition that the Army's DTD requirements go far beyond the needs of the modeling community, this plan proposes the DTD program be separated from EMIP. The plan proposed in this annex was developed in coordination with ETL and ESC recommends that ETL assume responsibility for the program. But, whether this means ETL will do the work in-house, by contract, or through DMA is not certain. In fact, the work done on this annex has added momentum to ETL's efforts to persuade DMA to reexamine its position on not producing interim terrain data to meet Army needs before the Mark 90 system becomes operational.

tt. COMMENT (Submitted by Assistant Chief of Engineers): This plan relies on TRADOC Analysis Command (TRAC), Concepts Analysis Agency (CAA), and the Engineer School to accomplish critical aspects of the plan. TRAC will

improve the engineer representation in the high-resolution CASTFOREM model, and CAA will work on the engineer portions of the low-resolution FORCEM model. The Engineer School will accept engineer family of models for operation and maintenance. We may need memorandums of understanding with all parties to assure that everyone understands what is expected from each other. These understandings would help us all as we implement the EMIP Plan during a time of personnel turbulence.

ESC RESPONSE: Agree. ESC has taken the first step by obtaining letters of support.

uu. COMMENT (Submitted by TRAC-WSMR): Page 17, III-15a(1). Although the document is well written, there is evidently some misunderstanding on how engineering operations are played in CASTFOREM. There is definitely an explicit play of engineering functions. Minefields may be pre-emplaced or artillery delivered. When units pass through a minefield, a one-on-one encounter takes place. The current logic is portrayed in the CASTFOREM Methodologies on pages 3-123. Explicit responses determined by decision tables then can bring into play any desired effects such as breaching, bulling, calling in Engineer units, slowing or stopping movements, going only through cleared lanes once the minefield is breached, etc.

ESC RESPONSE: Comment noted. The text describing engineer representation in CASTFOREM has been updated to correct any misunderstanding.

vv. COMMENT (Submitted by TRAC-WSMR): Page A-2, Footnote. CASTFOREM's most extensive documentation is in the recently published manual on CASTFOREM Methodologies.

ESC RESPONSE: ESC has updated the EMIP Plan to reflect the information published in the five volumes of CASTFOREM documentation in February, 1988.

ww. COMMENT (Submitted by TRAC-WSMR): Page A-3, 4b. 4:1 run times are scenario-dependent and machine-dependent. On a VAX-8800, typical run time to battle ratios are 2:1 or even less.

ESC RESPONSE: Corrected.

xx. COMMENT (Submitted by TRAC-WSMR): Page A-3, 4c. We believe CASTFOREM to have the best representation of Engineering activities in a model of its class. It may be limited but only because of the situation it was built to represent. TRAC-WSMR modelers worked very closely with the Engineering School in developing the capabilities represented in CASTFOREM (covered on Page A-5, 4g).

Vehicles entering prepared fighting positions are afforded extra cover which, in turn, makes them harder to hit. Kill probabilities are not degraded. PK/H remains the same.

Obstacles, particularly minefields, are played explicitly. A vehicle suffers damage only if it detonates a mine and then only probabilistically. There are no predetermined kills or times assessed. Breaching assets are played explicitly and are not assumed to be available.

ESC RESPONSE: Corrected. A footnote has been added because TRAC-WSMR has yet to publish the results of their verification of the decision tables which support the mobility and counter mobility in the Engineer Module.

yy. COMMENT (Submitted by TRAC-WSMR): Page A-4, Para 4d. We are not sure we have reached the point of approval by the entire Army Community, but we are trying.

ESC RESPONSE: Corrected.

zz. COMMENT (Submitted by TRAC-WSMR): Page A-4, Para 4f. Several other Government agencies, as well as some contractors, have CASTFOREM. TRAC-WSMR is the model proponent and, as such, is responsible for model configuration control. Other agencies do run CASTFOREM.

ESC RESPONSE: The reference regards model proponentcy has been corrected in paragraph 4f. The comment regards other agencies has been reflected in paragraph 4i.

aaa. COMMENT (Submitted by TRAC-WSMR): Page A-5, Para 4h. Minefields and, in fact, all of the Engineer tactics used in the Counter mobility study are already in CASTFOREM and available to be used in all studies. Primarily, Engineering tactics are modeled "outside the model code" in generic decision tables. These decision tables may be moved from study to

study, as can other generic type tactical response decision tables (e.g., helicopter tactics, fire suppression, etc.). Most Army study scenarios using CASTFOREM play minefields. Thus, USAES will not have to push for modifications, perhaps, only insist that minefields be included in TRADOC standard scenarios.

ESC RESPONSE: ESC has updated the cited text to indicate that the countermobility study includes more than minefields and minefield breaching. Paragraph 4h(2) was rewritten to show that the TRAC-WSMR and USAES effort was centered around generating appropriate decision tables for countermobility systems and testing CASTFOREM with these decision tables in place.

bbb. COMMENT (Submitted by TRAC-WSMR): Page A-8, Para 6g. Artillery units may or may not be implicitly prepositioned in static firing positions.

ESC RESPONSE: Corrected.

ccc. COMMENT (Submitted by TRAC-WSMR): Page A-12, Bottom of Page. Missing or incomplete sentence.

ESC RESPONSE: Corrected.

ddd. COMMENT (Submitted by TRAC-WSMR): Page A-13, Top of Page. Missing or incomplete sentence.

ESC RESPONSE: Corrected.

eee. COMMENT (Submitted by Commander, BRDEC): BRDEC does not currently possess a running version of the CASTFOREM Model or Source Code. The Source Code was requested from TRAC WSMR on 25 February 1988. The US Army Armament Research Development Engineering Center (ARDEC) at Picatinny Arsenal, Dover, NJ, does possess a running copy of the model.

ESC RESPONSE: Corrected in paragraph 4i.

fff. COMMENT (Submitted by Commander, BRDEC): The discussion of CASTFOREM Model capabilities in Annex A is out of date. For example, run times per iteration with the VAX 8800 average under two hours (reference page

A-3); more than one breached lane is possible because it is a user input (reference page A-18); and RAMMS can be modeled (reference page A-13). Coordination with TRAC-WSMR indicates they will provide the information to update this Annex.

ESC RESPONSE: Corrected.

ggg. COMMENT (Submitted by Commander, BRDEC): Annex D (page D-11) states, "Engineer equipment must be identified at the individual item level." BRDEC recommends that a list of the specific systems that will be modeled be included in this Annex. It has been our experience that it is easier to model Engineer Equipment Systems while under development, than after the fact. ESC RESPONSE: Noted. An EFAM Advisory Group will be organized to provide detailed guidance to the model developers. Although not included in the EMIP Plan, a list of the specific systems to be modeled will be included in detailed Statements of Work.

hhh. COMMENT (Submitted by Commander, BRDEC): In addition to Engineer Equipment Systems already fielded, BRDEC also recommends that near and midterm systems be included. The code, if written in modular format, will allow a midterm system that is canceled before production to be merely "turned off." By including midterm systems, EFAM will not be obsolete by the time the model is finally completed.

ESC RESPONSE: Agree.

iii. COMMENT (Submitted by ETL): For Appendix E-1, recommend explaining the content, resolution, accuracy, and format of each data set displayed in legends. Also, why show all possible data sets in the legends when only one exists for an area? Showing one would help clarify graphics.

ESC RESPONSE: Appendix E-1 is provided as a quick reference, to show the individual and aggregate coverage of various data sets. The details on each data set are documented in the sources cited in the bibliography. The standard legend was used to allow a common coding pattern to help the reader cross reference figures and to simplify the graphic layout of the figures.

jjj. COMMENT (Submitted by ETL): Page E-4, Para 4, Line 10. After "specification," add the phrase, "as well as identify Special Terrain Data (STD) as the Army's stated high resolution DTD Requirements. Both TTD and STD will eventually serve as Army DTD sets of the future."

ESC RESPONSE: The paragraph has been revised.

kkk. COMMENT (Submitted by ETL): Page E-5, Para 6, Line 20. After "DTD", add the word "source."

ESC RESPONSE: The paragraph has been revised.

lll. COMMENT (Submitted by ETL): Page E-5, Para 6, Line 20. Delete "Army Field Units."

ESC RESPONSE: The paragraph has not been changed.
(Paragraph 9 discusses the fact that field units have limited capability to produce DTD.)

mmm. COMMENT (Submitted by ETL): Page E-6, Figure E-1. For the status of DTED (Level 2), add the word "very" in front of "limited."

ESC RESPONSE: The Figure has not been revised. The distinction between "limited" and "very limited" is too fine to appear in a summary table such as this.

nnn. COMMENT (Submitted by ETL): Page E-6, Figure E-1. For the status of DFAD (Level 1-C), add the phrase "limited coverage" after the word "sources."

ESC RESPONSE: The Figure has been revised.

ooo. COMMENT: Page E-6, Figure E-1. For the data set, change the word "WES" to "Mobility Data Base", and place the term "WES" parenthetically underneath the phrase, "Mobility Data Base." Also, for the feature density, change the entry, "100m" to 25-100m."

ESC RESPONSE: The Figure has been revised.

ppp. COMMENT (Submitted by ETL): Page E-6, Figure E-1. For the status, add the phrase, "limited coverage" after the word "Demonstration."

ESC RESPONSE: The Figure has been revised.

qqq. COMMENT (Submitted by ETL): Page E-7, Para 8.a(2). 1) TAC also transforms DTED to 5 1/4" Floppy Disk; 2) should a generic format be identified for ITD, TAC will probably manage contracts for producing Digital TTADB's; 3) support by TAC for ARTBASS production could be questionable since CAC may cancel their requirement for additional DTD to support ARTBASS.

ESC RESPONSE: The paragraph has been revised.

rrr. COMMENT (Submitted by ETL): Page E-9, Para 10. There is no mention of the A&E firms which are better-equipped than both BDM and JPL, for DTD production.

ESC RESPONSE: The paragraph has been revised.

sss. COMMENT (Submitted by ETL): Page E-28, Para 18.c., Line 1. FORCEM requires LOC networks; the majority of available DFAD (Level 1 1st Ed), does not have LOCs. Therefore, availability of DMA's DFAD to satisfy FORCEM is very limited.

ESC RESPONSE: ESC agrees with the observation. No change called for in the text.

ttt. COMMENT (Submitted by ETL): Page E-2-3, Para 27. ITD definition, while accurate for what DMA initially tried to do, does not accurately reflect Army's current description of ITD in general.

ESC RESPONSE: The definition has been revised.

LAST PAGE OF ANNEX I