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# VERIFICATION AND VALIDATION OF JOINT EXERCISE SUPPORT SYSTEM (JESS) 1.1 ENGINEER MODULE



## Fort Leavenworth

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# VERIFICATION AND VALIDATION OF JOINT EXERCISE SUPPORT SYSTEM (JESS) 1.1 ENGINEER MODULE

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This report represents the verification and validation of the engineer module of the Joint Exercise Support System (JESS). Based on the results of this analysis from data collected during a December 1988 exercise of JESS 1.1, the engineer module cannot be considered verified or validated.

Although the results of this analysis show that the module adequately represents the establishing of engineering features on the battlefield, the code and methodology that represent the effects of these features are incomplete and incorrect.


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19. ABSTRACT (continued)

Errors in the code, methodology, and supporting data base produce invalid results:

1. An armored vehicle launched bridge (AVLB) can breach an antitank ditch but not a road crater, even though both obstacles are represented in the model.

2. The survivability effect factors of fortified battle positions and the terrain effects factors are not being used independently. Therefore, only one factor will be used in the direct and indirect fire attrition.

3. Minefield attrition, to include discovery loss, should be applied to the lead vehicles rather than to all systems. A unit, through interactor control, can successfully bypass a minefield after discovery without incurring any loss.

4. Movement delays due to engineering features do not consider unit size or whether the unit is Blue or Red. This results in faster movement for larger units or slower movement for smaller units depending on how the data base is set up.

The results from JESS 1.1 engineer tests were reviewed by subject matter experts and compared with current field manuals.

Sensitivity tests were conducted on JESS 1.1 engineer module to determine the effect of changing survivability levels on attrition and changing the percent completion of engineer obstacles on unit movement rates.

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Although the results of this analysis show that the module adequately represents the establishing of engineering features on the battlefield, the code and methodology that represent the effects of these features are incomplete and incorrect.

Errors in the code, methodology, and supporting data base produce invalid results:

1. An armored vehicle launched bridge (AVLB) can breach an antitank ditch but not a road crater, even though both obstacles are represented in the model.

2. The survivability effect factors of fortified battle positions and the terrain effects factors are not being used independently. Therefore, only one factor will be used in the direct and indirect fire attrition.

3. Minefield attrition, to include discovery loss, should be applied to the lead vehicles rather than to all systems. A unit, through interactor control, can successfully bypass a minefield after discovery without incurring any loss.

4. Movement delays due to engineering features do not consider unit size or whether the unit is Blue or Red. This results in faster movement for larger units or slower movement for smaller units depending on how the data base is set up.

The results from JESS 1.1 engineer tests were reviewed by subject matter experts and compared with current field manuals.

Sensitivity tests were conducted on JESS 1.1 engineer module to determine the effect of changing survivability levels on attrition and changing the percent completion of engineer obstacles on unit movement rates.

1. Purpose. Effectiveness on the battlefield is increased by the support that combat units receive from sister organizations. These units provide aid in maneuvering friendly forces and obstructing enemy movement in concert with the ground commander's overall scheme of maneuver. The purpose of this report is to determine the accuracy of the Joint Exercise Support System (JESS) 1.1 engineer representation in support of ground maneuver operations.

2. Problem. To be effective training aids, training simulations must provide for battlefield reality. The contribution of engineer support in JESS 1.1 depends upon the variety of tasks that can be performed and the effects that these tasks have on both friendly and enemy units. This interim report examines the existing capabilities of the JESS 1.1 engineer module and uses various analytical techniques to determine if the engineering support available to the unit commander is accurately represented.

3. Objectives.

a. Conduct a technical review with available documentation to ensure the suitability of the algorithms and model structure.

b. Verify the existing data bases as to source, data definition, and any data transformations that may be required to tie the simulation together.

c. Conduct a sensitivity analysis to determine the range over which JESS 1.1 provides credible results.

d. Make recommendations regarding model modification to ensure consistency.

e. Validate module results with subject matter experts (SMEs).

4. Limitations.

a. The Vector-In-Commander (VIC) model was selected as the reference model for the verification and validation (V&V) of JESS. Current engineer representation in VIC is limited. An Engineer Model Improvement Program (EMIP) plan is currently underway to improve model capabilities. Subject matter expert review of the results is the basis of this validation effort.

b. During the JESS 1.1 V&V exercise, engineer tasks were performed by teams that were formed at battalion-sized units. A sufficient amount of engineer supplies was available for use. For the purpose of this analysis, teams performing engineer tasks were not subjected to indirect fire (artillery or air) but were subjected to direct fire in some of the test cases.

c. Although source code for JESS 1.1 was not available, Software Design Documentation Language (SDDL) listings of the code were available for software analysis.

5. Assumptions.

a. Unit survivability in fortified battle positions is a function of the Lanchester direct fire attrition coefficients. The analysis of these coefficients is part of the direct fire review and is assumed to be correct for this discussion.

b. Unit movement is a function of units' base speed, terrain characteristics, and obstacles. The unit speed before modifications by obstacles is assumed to be correct for this analysis.

6. Methodology. This method of V&V analysis is based on the JESS 1.1 V&V study plan that was approved by a quality control board (QCB) in November 1988.

a. Verification analysis.

(1) An evaluation of the engineer capabilities consisted of a review by technical experts at the United States Army Engineer Studies Center (USAESC), Fort Belvoir, Virginia.

(2) A comparative analysis of published documentation with model output was a result of engineer orders issued by controllers at work stations.

(3) A structured walk-through of the SDDL listings provided some architectural linkages with other modules and implementation of the algorithms that drive engineer effects.

(4) A test run matrix for the JESS data exercise, December 1988, produced data for analysis.

b. Validation analysis.

(1) The engineer data base is currently under review by the United States Army Engineer School (USAES), Fort Leonard Wood, Missouri.

(2) Analysis of data results was conducted by SMEs from the USAES liaison at the TRADOC Analysis Command Operations Directorate (TRAC, OD), and USAES.

(3) A sensitivity analysis of minefield lethality and survivability due to fortified battle positions was conducted as part of this analysis.

c. Essential elements of analysis (EEA).

(1) Does the engineer module represent appropriate CS functions at the corps/division echelon?

(2) Do the represented engineer functions perform to published documentation and/or design specifications?

(3) What nonlethal effects do engineer assets have on the battlefield?

(4) What is the average number of vehicles killed by an engineer-emplaced minefield?

d. Measures of effectiveness (MOE).

(1) Evaluation to include military expertise and documentation review.

(2) Engineer resources used.

(3) Time to perform engineering functions.

(4) Time delays to units encountering engineer obstacles.

(5) Survivability of prepared defensive positions.

(6) System losses due to minefields.

7. Analysis. A description of the engineer module in appendix D is provided as background for the analysis. Figures A-5 through A-10 in appendix A, extracted from JESS documentation identify the algorithms used in the engineer module.

a. To verify the engineer module, a comparison with design goals was performed, as well as a review of published documentation and source code and the testing of the module options to ensure that the model performed as documented. This verification responds to EEA 1 and 2.

(1) There are no published design goals for the engineer module. In lieu of the design goals, a review of an EMIP plan was conducted. This program, managed by the USAESC, is designed to ensure that engineers are properly represented in land combat models. Under this program, USAESC has already published an EMIP plan for the evaluation and improvement of three combat development models: Combined Arms and Support Task Force Evaluation Model (CASTFOREM), VIC, and Force Evaluation Model (FORCEM). USAESC is reviewing JESS as a medium-resolution training model. The EMIP plan has produced a list of desired engineer tasks to improve VIC that will be accomplished by TRAC-White Sands Missile Range (WSMR), Waterways Experiment

Station (WES), and Construction Engineering Research Laboratory (CERL). Figure A-1 in appendix A is the list of desired engineer tasks for VIC from the EMIP plan. Figure A-2 in appendix A shows the current engineer tasks in JESS 1.1.

(2) Documentation of the engineering module is contained in a section of the JESS 1.1 users' handbook. The handbook lists data needed to issue engineer orders and includes a model concept describing the methodology. There is also a data dictionary of the variables needed, a definition of the variables, a range of valid entries, and a default value for the variable. The analysts' guide is not available at this time. Also not available are the data sources, some data definitions, and an overview structure of the engineer module showing clear interactions with other modules such as movement and direct fire.

(3) Actual JESS 1.1 source code for the engineer module was not available, but a pseudocode listing in SDDL was available for analysis. This module centers around three procedures, ORDER.ENGINEER, ENGINEER.TASK.TEAM, and MOVE.ALONG.ROUTE.GROUND. See figures A-2, A-3, and A-4, appendix A, for the logic flows for these procedures.

(a) The ORDER.ENGINEER routine forms the engineer task teams by checking the order inputs for validity, creating the engineer task team, building a list of tasks to perform, checking the team for appropriate amounts of supplies and systems for requested tasks, and activating the engineer task team to start operation.

(b) The ENGINEER.TASK.TEAM represents the actual operations of the engineer task team (ETT). The team moves from the home unit to various task worksites and then home again after all tasks are completed. During this procedure, the teams incur attrition; they select the task to perform, perform the task functions, terminate the task for various reasons, and report alert messages to the game interactor.

(c) The MOVE.ALONG.ROUTE.GROUND represents the movement and other module interaction of explicit ground units. As units move, various unit conditions are checked and modified. Travel time for unit movement from one hexagonal cell (hex) to the adjacent hex is calculated in the GROUND.TIME.ESTIMATE routine. This estimated travel time considers terrain conditions, road factors, and river delays as well as engineer terrain modification activities that enhance and degrade unit movement. These engineer modifications consist of bridging tasks (engineer or fixed bridges), point obstacles, and road craters. The estimated travel time is then further modified by any delay due to minefields in the GET.MINEFIELD.DELAY. A final engineer effect that occurs in MOVE.ALONG.ROUTE.GROUND is the actual minefield attrition in the ASSESS.UNIT.MINEFIELD.ATTRITION routine.

(d) Other engineering activities that affect other areas of the model are "fortified battle position" and "repair runway." The battle positions, represented as attrition factors, enhance the unit's survivability when engaged in direct and indirect fire. "Runway repair" fixes a damaged runway and allows aircraft to take off.

(4) The initial test design created task teams to execute all 14 engineer tasks for both Blue and Red. Review of the SDDL determined that the software logic is independent of side (Blue or Red) and the tasks are directly data driven. This reduced the number of tests needed. The testing actually performed was as follows:

Blue - Engineer bridge (install, destroy, remove)
Fixed bridge (destroy, repair)
Minefield (install, breach)
Hasty minefield (install, breach)
Fortified battle position

Red - Point obstacle (create, breach)
Tank ditch (create, breach)
Minefield (install, breach)
Fortified battle position

Excursions - ETT in mission-oriented protection posture (MOPP)
ETT at worksite under fire
Survivability at night

(a) The data base used in the model verification testing of various engineer tasks was not validated at this time. The verification testing of the engineer task options produced results consistent with the input data provided.

(b) Engineer task option testing showed that appropriate systems were assigned to the task teams, appropriate supplies were consumed after the task was completed, and task duration times were maintained for task completion. When tasks were aborted or canceled, appropriate partial credit for work, supply consumption, and task duration times were consistent.

(c) Engineer task completion times corresponded with the data base provided for the exercise tests. Using approved data from USAES, the data base can be implemented without difficulty. The two excursion runs on the performance of the ETT while under fire and in MOPP showed consistency with published documentation although the amount of suppressive effect cannot accurately be determined.

(5) The following is a response to EEA 1. (Does the engineer module represent appropriate CS functions at the corps/division level?) The task list, figure A-1, appendix A,

should be considered a good starting point for appropriate engineer representation at a corps/division echelon until USAESC completes its review of engineer representation in training simulations. As a result of the review by USAESC, the list of desired engineer tasks for a corps/division-level model (VIC), figure A-1, was separated into four categories with corresponding JESS capabilities as follows:

(a) Countermobility. JESS 1.1 represents all desired tasks.

(b) Mobility. JESS 1.1 represents most of the desired tasks with the exception of the repair and maintenance of pioneer trails and forward-air landing facilities. It is noted that JESS does not represent forward-air landing facilities and that JESS does maintain airfields for fixed-wing aircraft.

(c) Survivability. JESS 1.1 represents all desired tasks.

(d) Sustainment engineer. JESS 1.1 does not represent any desired tasks.

(6) The following is a response to EEA 2. (Do the represented engineer functions perform to published documentation and/or design specification?) As mentioned before, there are no design specifications for JESS, only published documentation. The engineer module had previously undergone testing during functional validation 12 (FV) at Fort Hood in September 1988. There are no published results of that testing, but reports show that problems were found and corrections made prior to this analysis. Functions identified in the JESS 1.1 users' guide were tested and the results follow.

(a) All tested engineer tasks, as defined in paragraph 7b(4), were performed as described in available documentation.

(b) The task, "repair fixed runway," was not tested due to time considerations and interactions needed with other modules. A review of the SDDL determined that the task should function as documented.

(c) Although an armored vehicle launched bridge (AVLB) can be used to breach an antitank ditch, it cannot breach a point obstacle in the model. Additionally, upon removing the AVLB, the antitank ditch is still considered breached when, in actuality, an active obstacle should remain.

b. To validate the engineer module, a review of the data base and analysis of model results were performed. The analysis of model results consisted of sensitivity analysis of effects of engineer tasks on the battlefield.

(1) The engineer data base containing the task options including supply requirements and task duration times was initially supplied by USAES. Adjustment was performed by Government and contractor personnel to conform to JESS data requirements and the data base was resubmitted to USAES for final approval. These data, when received from USAES, will serve as a baseline data base supplied to the field.

(2) Table B-1, appendix B, contains the results of the analysis of the obstacle effects on unit movement which show that the time delays are a direct result of the engineer model parameter input data.

(3) Movement delay times through obstacles and crossing rivers appropriately represent degradation but they seem to be too slow. Delay times when bypassing obstacles should be no lower than the longest time to breach the obstacle as defined in the task option times. Crossing a river with a bridge should include representing the channeling effect the bridge would have on the unit. These delay times could be incorporated as changes to the data base.

(a) There is a 29-minute delay when bypassing an antitank ditch and a 59-minute delay when bypassing a point obstacle. These data agree with the values in the data base. SMEs will determine the appropriateness of the data elements.

(b) The movement over both the engineer and fixed bridges appears to be the same.

(4) Appendixes B and C show the results of sensitivity analysis of obstacle effects on unit movement, minefield lethality/time delays, and survivability effects due to increased levels of fortification.

(a) Minefield effects are a function of the capability or effectiveness of the minefield in terms of a percentage. This percentage or fraction affects the movement delay through and the lethality of the minefield. Upon initial installation, the tactical minefield is 100-percent capable or 50-percent capable for a hasty minefield. This percentage is reduced if an ETT does not have the required amount of time to complete the task. A minefield degradation factor is defined in the data input to reduce the percent capability of the minefield. This data input value and a unit probability of kill (Pk) are adjusted by a "bull-through" factor when the unit goes through a minefield in the attack or withdrawal operational state (OPSTATE). The percent capability of the minefield is then randomly reduced to reflect the effort of a unit moving through the minefield. The stochastic process is the result of a uniform distribution around the minefield degradation factor. This degradation factor reduces the capability of the minefield to determine delay times. The minefield capability is then applied to the Pk for the lethality effect of the minefield.

A random number is determined from a uniform distribution around the Pk, which is applied to all systems in the unit.

(b) Survivability effects are attrition multipliers representing the effects of the levels of fortified battle positions (FBP). The current data elements are as follows:

| FBP level | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| | 1.0 | 0.75 | 0.50 | 0.25 |

In reviewing the SDDL listings which are used for direct and indirect attrition, these factors are used as multipliers with other factors and the Lanchester attrition rates in determining the overall number of pending casualties. The factor is the result of computing the minimum of six multipliers shown as follows:

Factor = Min ((LVM), (LRFM), (LFM), (LUM), (LRVM), (LEDM))

where:
- LVM - Multiplier based upon terrain vegetation
- LRFM - Multiplier based upon terrain roughness
- LFM - Multiplier based upon fortification level
- LUM - Multiplier based upon urbanization
- LRVM - Multiplier based upon presence of river between engaging forces
- LEDM - Multiplier based upon elevation difference between engaging forces

The results displayed in table C-1, appendix C, show an increased survivability with additional levels of fortifications. These tests were performed in a nonvegetated, relatively flat terrain cell. Figure C-1 shows the strengths of the Blue unit after one combat assessment interval for each of the levels of fortification. Given the battle with the same unit performing the same tests in a heavily vegetated area, the results would be as shown in figure C-2, appendix C.

(5) The following is a response to EEA 3. (What nonlethal effects do engineer assets have on the forces on the battlefield?) Nonlethal effects are represented by movement delays as a result of engineer obstacles and unit survivability resulting from fortified battle positions.

(a) Movement delays are functions of different obstacle types and percent completion of the obstacle. They have a cumulative effect that degrades unit speed by increasing the amount of time it takes to travel to the next position. Bridge factors (both engineer bridge and fixed bridge) have a negligible effect on movement speed once the bridge exists. These delays represent implicit bypass operations of antitank ditches and point obstacles and not actually breaching operations. There will be also be a delay through a minefield, not as a bypass operation but as a "bull through" with an added delay penalty if the unit is in an attack or withdrawal OPSTATE.

(b) Survivability, represented as attrition multipliers, is grouped together with five other factors to reduce the number of pending casualties. Any of the other multipliers could override the effect of fortifications and not give a defending unit the additional credit of survivability that it should be getting.

(6) The following is a response to EEA 4. (What is the average number of vehicles killed by an engineer-emplaced minefield?) Minefields cause attrition of a fraction of a unit's systems. This fraction is uniformly distributed around a Pk (currently set at .1) for both Blue and Red attrition for engineer minefields and artillery delivered minefields. The data represents a generic minefield that would be produced by the given amount of mines in the engineering task at an appropriate density.

(a) The lethality includes both discovery loss and losses incurred while moving through the minefield. The lethality data of the minefield was compared with appropriate minefield lethality data used for VIC. The usage of the data is inconsistent with the desired results of the methodology.

(b) *Minefield lethality is applied to all combat* and CS systems in the unit.

8. Conclusions. Based upon the above analysis and results, the engineer module cannot be considered verified nor validated.

a. Comparing the engineering capabilities of JESS with desired VIC tasks, JESS looks good. However, recommendations for enhancements to the current representation cannot be submitted to the JESS Configuration Control Board (CCB) until USAESC completes its evaluation on training simulations and the Combined Arms Training Activity (CATA) decides what should be in the training device requirements (TDR).

b. The users' manual is good and is an acceptable interim substitute until the analysts' guide is released.

c. The data dictionary has most engineer data in one location, but there are data in other areas which are not referenced in the engineer section and, therefore, the data definitions and initial values are difficult to locate.

d. Engineer data received from the USAES should serve as a valid baseline data base for use at the user sites.

e. Assessing combat once every 60 minutes overshadows the effects that would normally occur within this time interval. As shown in table B-1, appendix B, the time it takes for a unit to encounter an antitank ditch would not have as much effect if the unit could pass through the area within the assessment interval. The unit would be delayed in moving to its objective, but no casualties would be assessed unless the unit would be in contact at the hour interval.

f. Representation of an AVLB is incomplete. The AVLB should also breach point obstacles.

g. The analysis shows that the fortified battle position does have the desired positive effect on the battlefield. The implementation of attrition multipliers, to include fortifications, appears to possibly negate their effect. The six attrition multipliers, although having similar effects on lethality are independent and should not be grouped together; they should be considered as one overall lethality factor.

h. Minefield discovery methodology does not correspond to attrition implementation.

i. Movement delay factors do not consider unit size or whether the unit is Blue or Red.

9. Recommendations.

a. Upgrade the data dictionary documentation. Consolidate the engineer data in one location or make references to all engineer data elements within one area in the engineer data dictionary.

b. Implement new data from USAES.

c. Consider reducing the combat assessment interval.

d. Complete the representation of the AVLB capability.

e. Change the application of the fortification multiplier in the computation of combat attrition. Separate the six attrition multipliers to represent the cumulative effect on combat attrition.

f. Expand the number of movement delay factors to account for unit size and side (Blue or Red).

## APPENDIX A

### TASK, LOGIC, AND METHODOLOGY

#### 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 air landing facilities

#### Survivability

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

#### Sustainment Engineer

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

#### Topographic Engineer and Fighting as Infantry

None

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

NOTE: This was extracted from the Engineer Model Improvement Program Plan, USAESC.

Figure A-1. Desired engineer tasks for VIC

Function of routine

Receives order from workstation and checks input for validity
Creates ETT process
Sets up task parameters
Activates ETT process

Routine performs above functions on the following orders and tasks:

Order type -

1 - Form engineer task team
2 - Report engineer task team
3 - Abort engineer task team
4 - Cancel engineer task

ETT task type -

1 - Repair fixed bridge
2 - Destroy fixed bridge
3 - Create point obstacle
4 - Breach point obstacle
5 - Create tank ditch
6 - Breach tank ditch
7 - Install minefield
8 - Breach minefield
9 - Install hasty minefield
10 - Fortify battle position
11 - Install engineer bridge
12 - Remove engineer bridge
13 - Destroy engineer bridge
14 - Repair airfields

Figure A-2. Logic of ORDER.ENGINEER

| Logic | Executable routine |
|---|---|
| Select task | |
| Check for shortages | ETT.CHECK.HOME.UNIT.FOR.SYSTEMS.AND.SUPPLIES |
| Draw equipment from home unit | ETT.DRAWS.SYSTEMS<br>ETT.DRAWS.SUPPLIES |
| Report shortages if necessary | ETT.SEND.SHORTAGE.REPORT |
| Process appropriate team activity: | |
| If no more tasks, send ETT home | ETT.CREATE.ARRIVE.HOME.ACTIVITY |
| Send ETT to next task site | ETT.CREATE.ARROVE.WORK.ACTIVITY |
| Check worksite and start work | ETT.ARRIVE.WORK |
| Consume supplies | ETT.END.WORK |
| Modify terrain | ETT.MODIFY.TERRAIN |
| Task team attrition | ETT.TAKE.ATTRITION |
| Relocate team to complete withdrawal from worksite | ETT.WITHDRAW |
| Relocate team at home, return systems and supplies | ETT.ARRIVE.HOME |
| Clean up activity and close activity | ETT.CHECK.ABORTS |

Figure A-3. Logic of ENGINEER.TASK.TEAM

GROUND.TIME.TO.NEXT.HEX

  GROUND.TIME.ESTIMATE

    GET.DELAY,FACTOR

      Time delay from current location to next hex
      Add river-crossing delay to include bridge (engineer and fixed) factors
      Add point obstacle delay
      Add antitank delay

    GET.MINEFIELD.DELAY

      Considering lanes and minefield capability

ASSESS.UNIT.MINEFIELD.ATTRITION

  Considering movement OPSTATE lanes and minefield capability

PUT.UNIT.IN.NEW.HEX

  MINEFIELD.WARNING

    Of upcoming minefield at next hex side

Figure A-4. Logic of MOVE.ALONG.ROUTE.GROUND

$$
\begin{aligned}
T_{\text{actual travel time}} = \mu_{\text{MOPP}} * \\
&\{\mu_{\text{unit status}} * \mu_{\text{units in new hex}} * \\
&[\,(\mu_{\text{hex conditions}} * T_{\text{base travel time}}) \\
&+ \delta_{\text{river crossing}} + \delta_{\text{mines}} + \delta_{\text{hex edge obstacles}}\,] \\
&+ \delta_{\text{arty displacement}} + \delta_{\text{ADA displacement}}\}
\end{aligned}
$$

Figure A-5. Unit travel time

$$\delta_{\text{hex edge obstacles}} = \delta_{\text{point obstacle}} + \delta_{\text{anti-tank ditch}}$$

Values for $\delta_{\text{point obstacle}}$ and $\delta_{\text{anti-tank ditch}}$ are specified in the database.

Figure A-6. Hex edge delay

$$\delta_{\text{river crossing}} = \frac{1}{C_{\text{eng bridge}} + C_{\text{fixed bridge}}}$$

where,

$$C_{\text{eng bridge}} = \frac{\text{number of engineer bridges}}{\text{river delay( river size )} * \text{engineer bridge factor}}$$

and,

$$C_{\text{fixed bridge}} = \frac{\text{\% capable of the fixed bridge}}{\text{river delay( river size )} * \text{fixed bridge factor} * 100}$$

The values for river delay (for each river size) and the engineer and fixed bridge factors are specified in the data base.

Figure A-7. River-crossing delay

$$\delta_{\text{mines}} = \left(\delta_{\text{lane}} + \frac{(\delta_{\text{no lane}} - \delta_{\text{lane}}) * (\%cap_{\text{mines}} - \%cap_{\text{lane}})}{\%cap_{\text{mines}}}\right) * \frac{\%cap_{\text{mines}}}{100}$$

where,

$\delta_{\text{lane}}$ = delay caused by the minefield with a friendly lane
$\delta_{\text{no lane}}$ = delay caused by the minefield without a friendly lane
$\%cap_{\text{mines}}$ = percent capability of the minefield
$\%cap_{\text{lane}}$ = percent capability of the friendly lane through the minefield.

The values for $\delta_{\text{lane}}$ and $\delta_{\text{no lane}}$ are specified in the database.

Figure A-8. Minefield delay

$$\% \text{ minefield causing attrition} = \% \text{ cap}_{minefield} - \% \text{ cap}_{lane}$$

$$Pk_{minefield} = \text{MINEFIELD.UNIT.PK} * \% \text{ minefield causing attrition}$$
$$[* \text{ BULL.THROUGH.FACTOR}]$$

$$\text{minefield casualties} = \text{uniform distribution } (0., Pk_{minefield})$$

$$\text{mf.deg.factor} = \text{MINEFIELD.DEGRADATION.FACTOR } [* \text{ BULL.THROUGH.FACTOR}]$$

$$\text{mf.degradation} = \text{uniform distribution } (0., \text{mf.deg.factor})$$

$$\text{new } \% \text{ cap}_{minefield} = (\% \text{ cap}_{minefield} - \% \text{cap}_{lane})$$
$$* (1. - \text{mf.degradation})$$

The values for MINEFIELD.DEGRADATION.FACTOR, BULL.THROUGH.FACTOR, and MINEFIELD.UNIT.PK are specified in the database.

Figure A-9. Minefield attrition

Fwl factor = Minimun (LVM, LRFM, LFM, LUM, LRVM, LEDM)

Where these factors are multipliers that raduce the effectiveness of the killer systems based upon the following characteristics:

LVM - three levels of vegetation

LRFM - three levels of terrain roughness

LFM - three levels of fortification

LUM - three levels of urbanization

LRVM - presence of a river (three types) between the engaging forces

LEDM - a factor for the greater elevation difference between the engaging forces

Figure A-10. Survivability (fortified battle positions)

# APPENDIX B

Table B-1. Mobility/countermobility results

| | | Unit Move Time (min.) |
|---|---|---|
| | **Antitank Ditch** | |
| Base case: | Tank regiment - six-kilometer (km) move<br>Smooth terrain, loose surface road | 22 |
| Test: | With antitank ditch | 51 |
| Sensitivity: | Partial antitank ditch (38 percent) | 23 |
| | With antitank ditch and AVLB | 22 |
| | **Point Obstacle** | |
| Base case: | Motorized rifle regiment, six-km move<br>Gently rolling terrain<br>Hard surface road | 27 |
| Test: | With full point obstacle | 86 |
| Sensitivity: | Partial point obstacle (36 percent) | 86 |
| | **Engineer Bridge** | |
| Base case: | Mechanized battalion, six-km move<br>Medium river (without bridge) | 67 |
| Test: | With full engineer bridge (nine spans) | 21 |
| Sensitivity: | Partial engineer bridge (one span) | 67 |
| | Multiple engineer bridges (21 spans) | 22 |
| | **Fixed Bridge** | |
| Base case: | Armored battalion, six-km move<br>Medium river (with fixed bridge) | 21 |
| Test: | With fixed bridge destroyed | 65 |
| Sensitivity: | Partial fixed bridge (37 percent) | 65 |

Table B-1. Mobility/countermobility results (continued)

## Deliberate Minefield

| | | Unit move Time (min) | Attrition percent |
|---|---|---|---|
| Base Case: | Mechanized task force battalion six km move Marsh terrain | 38 | - |
| Test: | With friendly minefield | 67 | - |
| | With enemy minefield | 95 | 7 |
| Sensitivity: | Breached enemy minefield | 67 | - |
| | Partially breached Enemy minefield (17 percent) | 90 | 14 |

## Hasty Minefield

| | | Unit move Time (min) | Attrition percent |
|---|---|---|---|
| Base case: | Mechanized task force battalion six-km move Smooth terrain | 28 | - |
| Test: | With friendly minefield | 42 | - |
| | With enemy minefield | 54 | 5 |

## APPENDIX C

Table C-1. Survivability results

Case: Fortified battle positions of Blue mechanized force Battalion (defend) vs Red tank regiment attack) - day

| Fortified position level (Ø through 3) | Combat assessment interval 1 (Percent unit strength) | 2 | 3 |
|---|---|---|---|
| Ø (Blue) | 43* | | |
| (Red) | 91 | | |
| 1 (Blue) | 55 | 28* | |
| (Red) | 91 | 87 | |
| 2 (Blue) | 63 | 33* | |
| (Red) | 91 | 86 | |
| 3 (Blue) | 82 | 64 | 43* |
| (Red) | 91 | 85 | 79 |

*Breaks contact with enemy from fortified position

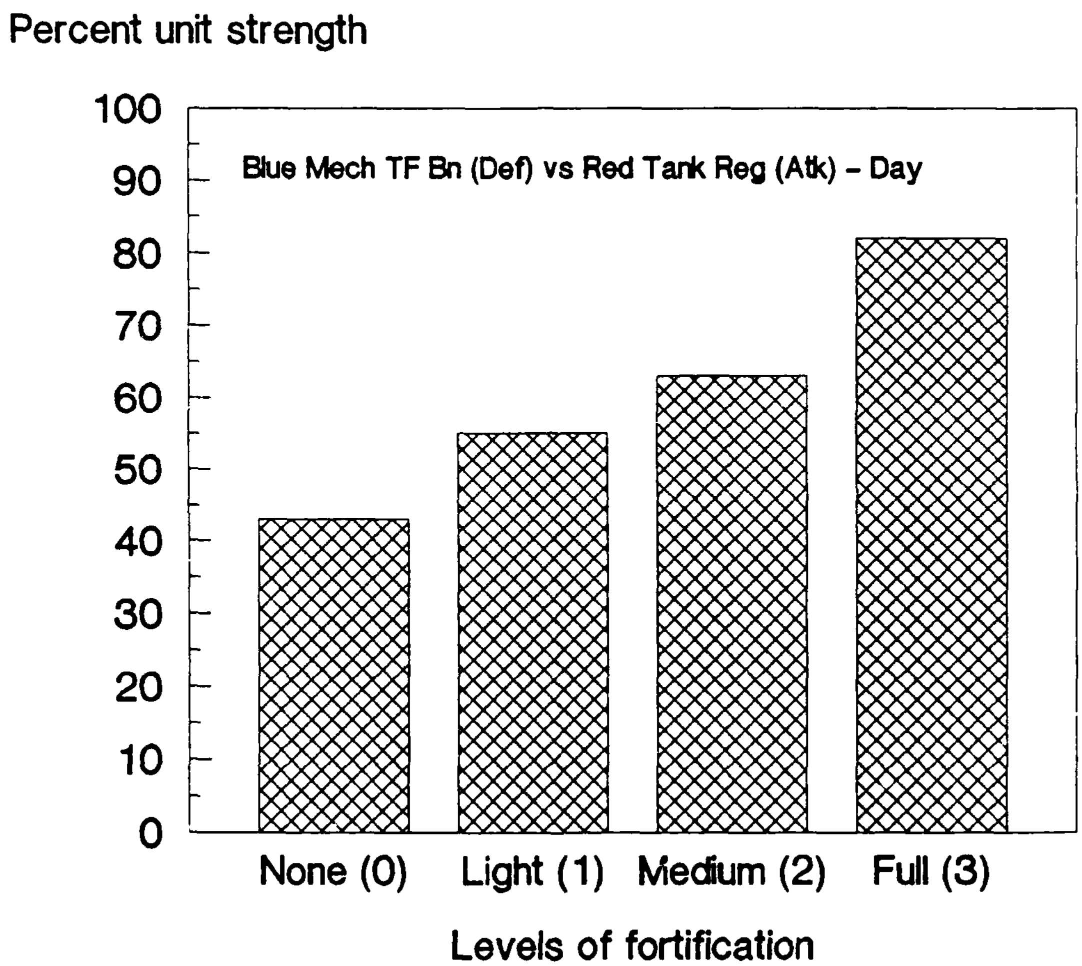


Figure C-1. Survivability in battle positions

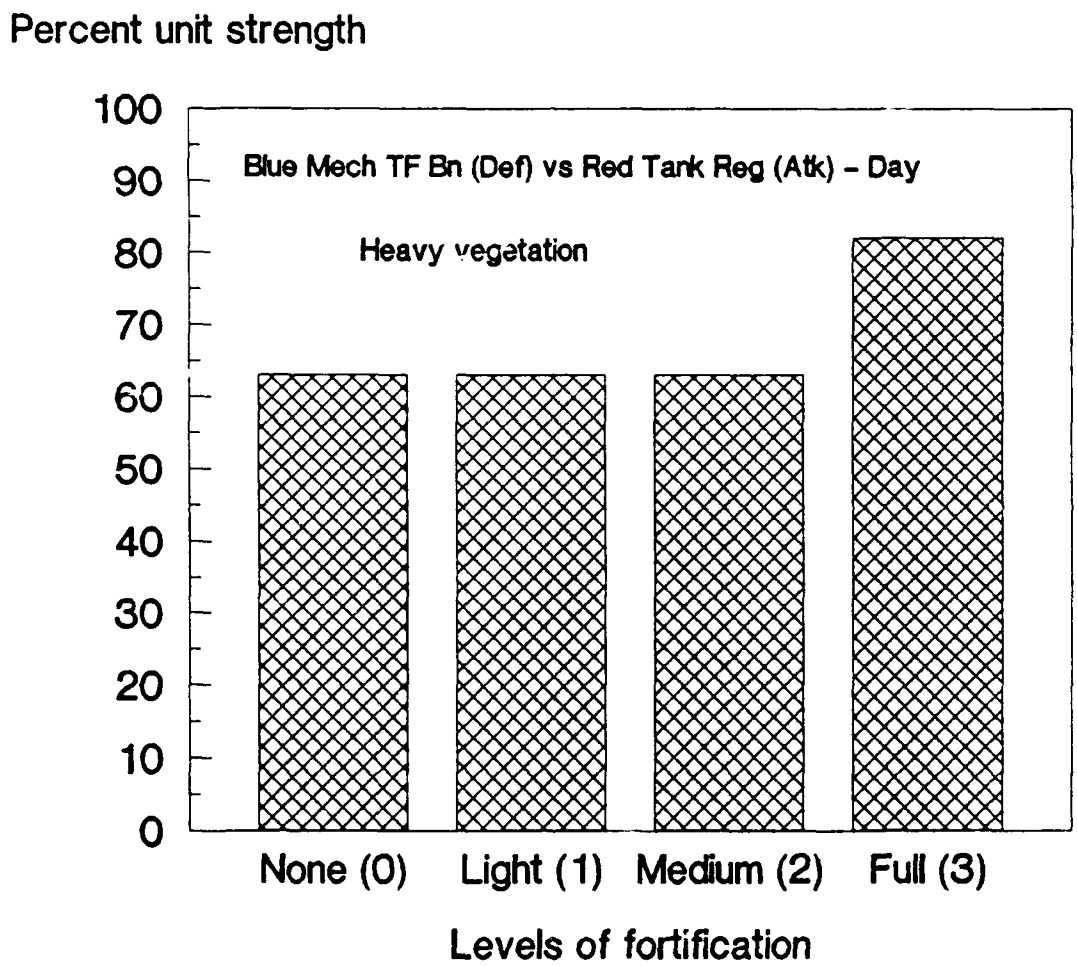


Figure C-2. Survivability in battle positions in heavy vegetation

## APPENDIX D

### DESCRIPTION OF JESS 1.1 ENGINEER MODULE

D-1. This module represents the modifying of the terrain by various manmade features (minefields, obstacles, battle positions, etc.). The representation includes effects that these features have on the rest of the battlefield. Orders to perform engineer functions are issued by a game interactor or controller for either the Blue or Red side. These orders can be to form, abort, and cancel engineer operations (or tasks) that are performed by an engineer task team (ETT). An additional order that can be issued for engineer tasks is "magic engineer." These "magic" orders are issued only by the senior controller for the automatic building, destroying, etc., of any engineer task (except for engineer bridge). These orders modify the terrain immediately, take effect immediately, and do not consume supplies.

D-2. The engineer data base contains data to describe the engineer tasks, model parameter data, and bridging requirement data.

a. Each task has up to five options. Each option consists of the number of supplies and systems needed and a duration time to perform the specific option of that task. The appropriate option is automatically selected based upon the lowest duration time and the supplies and equipment that are in the task team.

b. Model parameter data contain the ETT speed, factors, thresholds, and minefield probability of kill (Pk) for the performance of the ETT and the engineer obstacles.

c. Bridging requirements data contain the number of bridging sections, or spans, needed to build a specific bridge type over a specific river size.

D-3. The modifying of terrain with manmade features starts when an order is issued that creates an ETT to perform engineer tasks. The ETT is formed to perform any of 14 different engineer tasks. When an ETT is formed, it obtains the necessary supplies and systems from its home unit and proceeds to a worksite to begin its task. As the ETT completes a task, it proceeds to the next worksite to perform the next task. When the ETT completes all of its tasks (up to four tasks per order), it returns to its home unit and returns its remaining supplies and systems. The home unit can be any unit that has the appropriate supplies and systems needed to perform the engineering task. The controller can also issue orders to either abort an engineer task team or cancel an engineer task. In both cases, work will stop immediately, and partial credit will be given. Aborting an ETT will cause the team to return home immediately, while canceling a task causes the team to proceed to the next task.

a. When forming an ETT, the team must have enough supplies and equipment to perform its tasks, or the task orders are rejected. Supplies are consumed when the task is completed; equipment is not.

b. ETTs are vulnerable to attrition due to direct and indirect (artillery and air) fire, but they do not fight back during ground combat. Damage to an ETT is reflected at the home unit when the ETT returns home or is destroyed in the field.

c. The ETT will attempt to withdraw when a capable enemy unit occupies an adjacent hex unless the team is accompanied by a capable friendly unit (in the same hex). If the ETT is forced to withdraw, the task is aborted, partial credit is given for any interrupted work, and the team begins to move one hex away and is vulnerable to attrition during the withdrawal.

d. Tasks that are interrupted due to attrition will receive partial credit. If the ETT is not killed, the ETT's task list will be reassessed. Work will resume under the quickest option if the team has enough operational equipment. If the task cannot be resumed, it will be terminated, and the team will proceed to its next task or return home. If the ETT is killed, it is destroyed in place. If the ETT is overrun by a capable enemy unit, all team personnel are killed, and all equipment is abandoned.

e. ETTs move along straight-line paths between worksites and their home units. Movement paths are constructed to avoid enemy units, and paths around the enemy units are determined with a travel delay that is added to the straight-line travel time. Teams are not subjected to attrition along the route to a worksite or returning to the home unit.

f. ETTs are subjected to chemical contamination while at the worksite, and the work rate will be slowed as the team is considered contaminated. Team contamination is not transferred to the home unit upon its return.

g. In the event of a nuclear attack at the worksite, all ETT personnel will be killed and all equipment will be abandoned. Partial credit will be given for any interrupted work. In the event of nuclear contamination at the worksite, the work rate will be slowed as for chemical contamination.

D-4. As mentioned previously, engineer tasks are designed to build or destroy various manmade features. These features become part of a dynamic terrain data base that overlays the physical constant terrain data base. A brief description of the constant terrain data base is necessary to understand the effects of engineer tasks.

a. Terrain is divided into hexagonal cells. Each cell (hex) is 3.0 km side to side, and each side is 1.73 km. Units move from an offset of hex center to an offset of the center adjacent hex.

b. Roads are located from the center of one hex to the center of an adjacent hex. Roads enhance movement over the normal terrain characteristics. The established road types are as follows: 0 - no road, 1 - loose surface, 2 - hard surface, and 3 - dual highway.

c. Rivers are located along hex edges. Rivers restrict movement as units move from one hex to another. The established river types are as follows: 0 - no river, 1 - small river, 2 - medium river, 3 - large river, and 4 - impassible. River value 4 sets an impassible condition which prevents units from crossing that hex edge. This boundary may actually represent a land/water boundary or a political boundary.

d. Fixed bridges normally exist when a road crosses a river.

D-5. The 14 engineer tasks that can be performed represent 7 different features that can be built (installed or created), destroyed, or breached.

a. Antitank ditches can be created or breached. A ditch can only be created where none exist. An antitank ditch breach order or an engineer bridge install order for an armored vehicle launched bridge (AVLB) can be used to breach a tank ditch. When an AVLB is used to breach a tank ditch, the "remove/destroy engineer bridge" tasks must be used to reactivate the existing antitank ditch rather than creating another antitank ditch. Antitank ditches cause travel delays on the edge where they are created. The capability of an antitank ditch must be greater than the ANTITANK.DITCH.THRESHOLD to cause delays.

b. Engineer bridges can be installed, destroyed, or removed. These bridges can only be installed to span rivers with an appropriate number of bridge sections. An AVLB can breach an antitank ditch. Only an enemy engineer bridge can be destroyed, and only a friendly engineer bridge can be removed. An antitank ditch becomes reactivated when the AVLB that was installed to breach the ditch is removed or destroyed. Orders for engineer bridges will not affect fixed bridges. Units will incur river delays while crossing a river without a bridge, while multiple engineer bridges will reduce the effect of the river delay.

c. Fixed bridges can be repaired or destroyed. There must be a damaged fixed bridge (bridge with a capability of less than 100 percent at the worksite for a fixed bridge to be repaired. The capability of a fixed bridge must be above the FIXED. BRIDGE.THRESHOLD data entry to be of use in crossing a river.

There must be a fixed bridge (with bridge capability greater than zero) for the bridge to be destroyed. Orders for fixed bridges will not affect engineer bridges. Units will incur river delays while crossing a river as a function of the capability of the fixed bridge.

d. Fortified battle positions can only be built up by an ETT. A battle position surrounds a hex and becomes a protective feature for any unit located within the hex. An ETT cannot fortify a battle position inside a hex that is surrounded by impassible barriers or occupied by an enemy unit. Up to three levels of protection can be built by repetitive fortification tasks in the same hex. Only a "magic" engineer order can remove a fortified battle position. Each level of protection from a battle position will enhance survivability against direct and indirect fire.

D-6. Minefields can be installed, installed hastily, or breached. There are four types of generic minefields, two engineer minefields (hasty-protective, and tactical), and two artillery minefields (target-of-opportunity and planned). A hasty-protective minefield is not as effective as a fully tactical minefield and normally uses fewer supplies and less time in installation. Upon installing either minefield, the installing team leaves lanes of its own color throughout the minefield, permitting friendly units to cross the minefield without suffering attrition. Installing a tactical minefield over a hasty minefield will bring the minefield up to a fully capable regular minefield. In breaching a minefield, the ETT will clear lanes through the entire minefield. An artillery-delivered minefield has no lanes when formed and can be breached by an ETT. The capability of the minefield (engineer or artillery) will be decreased every time a unit travels across it without using a lane. Upon discovering the minefield, the controller is warned, but no attrition takes place until after crossing the minefield. This warning allows the controller to either breach the minefield or maneuver to avoid the minefield. "Clearing" the minefield can only be accomplished by the senior controller who can magically delete the minefield. When crossing a minefield, a friendly unit will incur a chokepoint time delay with no attrition. An enemy unit will incur a minefield time delay and minefield attrition. An artillery-delivered minefield will cause attrition to either side until it is breached by the respective side. A unit will incur an additional BULL.THROUGH attrition and delay factor while crossing a minefield in either an attack or withdrawal moving posture. Both attrition and time delays are affected by the percent capability of the minefield. A minefield becomes ineffective when the percent capability of the minefield goes below the MINEFIELD.THRESHOLD value.

D-7. Point obstacles can be created or breached. They represent a road crater; therefore, a road must exist that is not completely obstructed for a point obstacle to be created. A point obstacle causes travel delays for units attempting to use the blocked road.

D-8. Repairing fixed runways can only be performed on damaged runways. An ETT cannot repair a runway inside a hex that is surrounded by impassible barriers or occupied by an emeny unit. The repairing of a damaged runway increases the runway length to allow different types of aircraft to take off.

D-9. To summarize, the effects of these manmade features take the form of movement delay time, minefield attrition, battle position protection, and airfield capability. Movement delay times are enhancements to movement rates, such as bridges over rivers, or impediments to movement rates, such as minefields, antitank ditches, and point obstacles. Minefield attrition is a uniform distribution around a Pk entry in the data base. This attrition is then applied evenly to all systems in the unit when it has decided to move through a minefield. Battle position protection is portrayed as factors applied to the Lanchester attrition coefficients based upon the amount of fortification. Improving airfield capability is accomplished by repairing damaged runways.

## APPENDIX E

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