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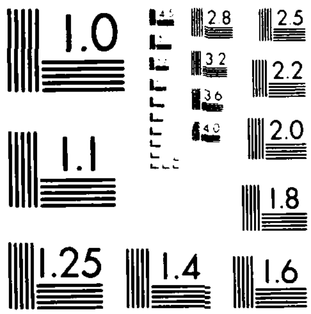

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A REVIEW OF SELECTED MODELS

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1 February 1982

Interim Report for Period 1 May 1980-1 February 1982

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

DNA 5452Z A Net Assessment of Tactical Nuclear Doctrine for the Integrated Battlefield, March 1981, presented alternative US/NATO corps tactical nuclear doctrines for evaluation. On the basis of the scenarios, doctrinal alternatives, and EEA, a statement of model/war game requirements was developed. An extensive search was conducted to identify the model(s)/war game(s) which might be used as analytic tools for the evaluation of tactical nuclear warfare doctrines. Four models were selected for extensive review against the criteria

20. ABSTRACT (Continued)

set forth in the statement of model/war game requirements: DIVWAG, ICOR, TAC ASSESSOR, and VECTOR-2. This report summarizes the statement of model/war game requirements, presents an assessment for the selected models, and makes one recommendation with rationale.

SUMMARY

ORI Technical Report 1775 (DNA 5452Z), March 1981, A Net Assessment of Tactical Nuclear Doctrine for the Integrated Battlefield presented alternative US/NATO corps tactical nuclear doctrines for evaluation. Five sequential areas of investigation were identified providing a problem structure that was amenable to quantitative methods:

- Survival, control, and support of forces
- Deployment and employment of selected tactical nuclear means organic to the corps
- Employment of tactical air resources in support of corps forces on the integrated battlefield
- Employment and support of combat forces in exploitation of opportunities created on the integrated battlefield
- Tactical nuclear weapons systems mix

A set of essential elements of analysis (EEA) was established for each area of investigation. The EEA defined the scope of planned analyses and should be subject to modification as results emerge from the quantitative investigation.

The EEA are focused on US/NATO corps warfighting capabilities with particular emphasis on the employment of division and corps tactical nuclear forces, and tactical air forces in support of US/NATO corps forces. Relative to the employment doctrine for these forces, particular emphasis was placed on force survivability, target acquisition capabilities of the corps and army groups, command control and communications (C^3), and provision of essential combat service support (CSS).

The dynamic battle representation requirements were a function of the area of investigation. Most of the survival EEA could be addressed by an analysis supported with a corps level simulation model of adequate fidelity. In addressing the control and combat service support EEA a war-gaming approach supported by application of relatively simple functional models to gain insights and develop specific concepts aimed at maintaining control of forces and providing essential CSS was anticipated. The ultimate requirement to field test the concepts developed was foreseen. For example, when investigating the employment options for Lance and atomic demolition munitions (ADM), the most promising of these employment options should be field tested for empirical validation of war-gaming results. Investigation involving tactical nuclear targeting will present the greatest analytic challenge. There is a definite need for controlled war-gaming at the corps and possibly higher levels. Review and analysis of the results from supporting simulations and games should support combat operations of the US/NATO corps over a range of likely scenarios.

On the basis of the scenarios, doctrinal alternatives, and EEA, a statement of model/war game requirements was developed. Eight functional areas of the system processes in the real world were identified:

- Operations planning
- Command control and communications
- Combat service support planning

- Intelligence and fusion
- Tactical maneuver of forces
- Combat support operations
- Combat service support operations
- Engagement and assessment

A model/war game hierarchy was constructed for these eight functional areas, the preprocessor and data base management, the battlefield environment, and the postprocessor. Input-process-output diagrams were developed for these eleven areas of consideration and the essential representations for the eight functional areas were established. These processes and essential representations comprised the statement of model/war game requirements.

An extensive search was conducted to identify the model(s)/war game(s) that would meet the criteria set forth in the statement of model/war game requirements. Any model/war game whose basic characteristics/attributes were similar to (or would be similar to in time for the model/war game enhancement phase) the statement of model/war game specifications was chosen for in-depth analysis. Four models were selected for extensive review:

- DIVWAG
- ICOR
- TAC ASSESSOR
- VECTOR-2

All four models were assessed via their current state of documentation and their strengths, weaknesses, and enhancement requirements were determined for each area of consideration.

The Division War Game Model (DIVWAG) is a division level, period-based war game that only has a batch processing capability. DIVWAG's operations planning methodology does not represent tactical nuclear planning and tactical air is not fully representative of the NATO system. C^3 activities are closely interfaced with processing and decision submodels, however, message volume, capacity, queuing, and command vulnerabilities to intercept, jamming and EMP are not represented and representation of attack by fire is inadequate for analysis purposes. CSS planning is well modeled in DIVWAG and only requires updating of sensor representation and vulnerabilities to electromagnetic pulse (EMP), deception, and jamming for intelligence and fusion. The gamer must plan, coordinate, and schedule all movement at game initialization. Unit mission, activity dependencies on operational states, and command control capabilities and vulnerabilities effects on the tactical maneuver of forces needs to be added to the DIVWAG system. DIVWAG models employment doctrine, rules, and constraints for conventional combat support, but not for chemical operations and precision guided munitions. No aspects of nuclear employment doctrine are represented and reconnaissance operations at the national level are not modeled. Support unit locations and road networks, stockage levels and support dependent on CSS processing and transport capabilities, and nuclear resupply are not modeled and CSS entities and activities are not subject to attrition. Precision guided munition, tactical nuclear delivery, and ADM employment logic and representation of battle-induced obscuration and electromagnetic influences are not present in DIVWAG system models.

ICOR requires extensive analysis and preprocessing to validate input parameters and does not provide interactive use at organizational levels above brigade. All decision-making and essential planning above battalion level require massive man-in-the-loop activities and lower level planning activities are not in the ICOR logic. All C^2 functions and decision-making above battalion level are primarily simulated by man-in-the-loop with no explicit representation of communications except for sensor operations, situation reporting, and operation delay times. C^3 operations procedures/profiles and vulnerabilities and division and brigade level situation assessment, decision-making, and orders issuance activities need to be represented in ICOR. CSS planning is not represented. ICOR does not realistically or timely represent the Combat Electronic Warfare and Intelligence (CEWI) Operations Center, the Tactical Operations Center (TOC), and vulnerabilities to EMP and deception since all occur at initialization or by man-in-the-loop. The effects of CSS status on the tactical maneuver of forces (combat activity) and the reduced effectiveness or loss of C^3 capabilities are not modeled. Chemical warfare capabilities and doctrine, combat engineering capabilities and doctrine, and reconnaissance at the national level are not simulated in ICOR and nuclear employment representation except for nuclear warhead resupply must be performed manually by man-in-the-loop. The explicit representation of CSS is limited to the supply of conventional ammunition and nuclear warhead resupply. Attrition rates are not based on engagement parameters - extensive data base development (analysis and preprocessing) is required to produce attrition data adequate to the full range of engagement possibilities. No documentation for nuclear weapon attrition methodology is present. All important effects of terrain, weather, and other environment factors, some of which are battle-induced, are ascribed to a host of indices for each terrain cell. ICOR's postprocessor contains no special analytic procedures extant to support analysis.

TAC ASSESSOR is a heavily data-dependent model requiring much time and care in preparing, modifying, and verifying the input data and data base. Tactical air planning is not fully representative of the NATO system and TAC ASSESSOR contains no logic for nuclear and chemical operations planning. Skip echelon and echelon bypass capabilities, EMP effects, deception, and CSS planning are not represented. TOC activities are limited to the corps level and CEWI operations are not modeled. Logic does not exist within the model to represent the effects of C^3 capabilities and vulnerabilities, CSS status, and exposure profiles for the tactical maneuver of forces. TAC ASSESSOR does not represent air-to-air operations, nor does it model nuclear and chemical deployment, employment, and operations doctrine. Aircraft and field artillery employment operations limitations prohibit TAC ASSESSOR from meeting requirements criteria in these areas. Explicit representation of CSS operations does not exist in TAC ASSESSOR. Ground combat is symmetrical, identification and acquisition processes are not modeled, and no engagement and assessment logic for nuclear and chemical employment is present. Weather, battle-induced obscuration, and nuclear-weapon-induced effects are not modeled. TAC ASSESSOR does not perform measure of effectiveness and statistical calculations and written reports only consist of event data.

The tactical decision rules (data input) drive the results of many of the areas of consideration and require careful and lengthy preparation and verification in VECTOR-2. The tactical decision rules specify user desired plans and contingencies and can be used to represent nuclear and chemical deployment procedures. VECTOR-2 does not represent EMP effects and communication degradation and only contains a vertical command element hierarchy. The tactical decision rules govern all resource allocations and distributions to appropriate groups, determine the effects of constrained supply levels on combat activity, manage intelligence at all levels, identify task organizations, specify major controls, allocate combat support, and define effects of unit CSS status. Logic to represent nuclear and chemical means, capabilities, and operations doctrine does not exist in VECTOR-2. CSS operations effects are implicitly represented in VECTOR-2 through the tactical decision rules. Nuclear and chemical engagement and assessment processes are not simulated and VECTOR-2 does not model battle-induced obscuration and its effects, electromagnetic influences, and nuclear-weapon-induced obstacles and their effects. VECTOR-2 calculates various measures of effectiveness but does not perform required statistical calculations.

Each model reviewed was assigned a grade based on required enhancements for each area of consideration. An overall rating for each model was determined and the models were ranked accordingly: (1) VECTOR-2, (2) DIVWAG, (3) ICOR, and (4) TAC ASSESSOR. Based on these results, VECTOR-2 was the model recommended. Enhancement efforts should be minimized by incorporating the Theater Force Evaluation by Combat Simulation (TFECS), a theater level methodology for quantifying the contributions of C^3, intelligence, and electronic warfare to the ability of a theater force to attain its objectives. Logic developed for the TFECS study involved representation of many of the areas of consideration and is ready for interface into VECTOR-2. Given these interfaces, VECTOR-2 needs only to be upgraded from a conventional warfare model to one that plays the integrated battlefield for use in the evaluation of doctrinal alternatives for the integrated battlefield.

PREFACE

This interim report of A Review of Selected Models follows DNA 5 ', A Net Assessment of Tactical Nuclear Doctrine for the Integrated Battlefi , March 1981 which presented alternative US/NATO corps tactical nuclear do s for evaluation. This report precedes the final report, Analysis of Some Alternative Tactical Nuclear Doctrines for the US/NATO Corps in the AirLand Battle in which an assessment of some alternative doctrines are made using two manual war games as tools.

This report has benefitted from the comments provided by Mr. Richard I. Wiles and the sponsor's representative, Lt. Col. Frank X. Reller, III.

Initial transcripts were prepared by Ms. Gwen Fisher and word processing support was provided by Ms. Norma Brinkley. Their patience and cheerfulness made our task easier.

Responsibility for the contents of this report rests solely with the authors.

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SECTION I

INTRODUCTION

1-1 BACKGROUND.

ORI Technical Report 1775 (DNA 5452Z), March 1981, A Net Assessment of Tactical Nuclear Doctrine for the Integrated Battlefield presented alternative US/NATO corps tactical nuclear warfare doctrines for evaluation. Five sequential areas of investigation were identified providing a problem structure that was amenable to quantitative methods:

- Survival, control, and support of forces
- Deployment and employment of selected tactical nuclear means organic to the corps
- Employment of tactical air (TACAIR) resources in support of corps forces on the integrated battlefield
- Employment and support of combat forces in exploitation of opportunities created on the integrated battlefield
- Tactical nuclear weapons systems mix.

A set of essential elements of analysis (EEA) was established for each area of investigation. The EEA defined the scope of planned analyses and should be subject to modification as results emerge from the quantitative investigations. The EEA focused on US/NATO corps warfighting capabilities with particular emphasis on the employment of divisional and corps tactical nuclear forces, and TACAIR forces in support of US/NATO corps forces. Relative to the employment doctrine for these forces, particular emphasis was placed on force survivability, target acquisition capabilities of the corps and army group, command control, communications, and provision of essential combat service support.

The net assessment focused on the warfighting capability at the corps level and was presented in the context of four scenarios:

- PACT strikes first

    I Pact forces deployed, NATO force in garrison, little warning

    II Both sides deployed, little warning

    III After a period of conventional conflict

- NATO strikes first

    IV After a period of conventional conflict

The dynamic battle representation requirements were a function of the area of investigation. Most of the survival EEA could be addressed by an analysis supported with a corps level simulation model of adequate fidelity. In addressing the control and combat service support EEA a war-gaming approach supported by the application of relatively simple functional models to gain insight and develop specific concepts aimed at maintaining control of forces and providing essential combat service support was anticipated. The ultimate requirement to field test the concepts developed was foreseen. For example, when investigating the employment options for Lance and atomic demolition munitions (ADM), the most promising of these employment options should be field tested for empirical validation of the war-gaming results. Investigation involving tactical nuclear targeting will present the greatest analytic challenge. There is a definite need for controlled war-gaming at the corps and possibly higher levels. Review and analysis of the results from supporting simulations and games should support determination of the mix of delivery systems and weapons yields required to support combat operations of the US/NATO corps over the range of likely scenarios.

On the basis of the scenarios, doctrinal alternatives, and EEA, a statement of model/war game requirements was developed. A review of appropriate combat models and war games was conducted and the model to be applied was recommended. The logic and data base modifications necessary to provide adequate representation of the scenarios and doctrinal alternatives should be specified. Thereafter, an analysis plan and appropriate run designs should be developed and reported. Concurrently, the specified model modifications and data base preparations should be accomplished. Finally, the run designs should be executed, the results should be reduced and analyzed, and a final report should be prepared evaluating the doctrinal alternatives investigated.

1-2 PURPOSE.

The purpose of this report is to summarize the statement of model/war game requirements and to discuss the results of the model/war game review within the context of the requirements.

1-3 SCOPE.

Eight functional areas of the system processes in the real world were identified:

- Operations planning
- Command control and communications (C^3)

- Combat service support (CSS) planning
- Intelligence and fusion
- Tactical maneuver of forces
- Combat support operations
- CSS operations
- Engagement and assessment

A model/war game hierarchy (Figure 1) was constructed for the eight functional areas listed above, the preprocessor and data base management, the battlefield environment, and the postprocessor. Input-process-output (I-P-O) diagrams were developed with respect to the hierarchy. The statement of model/war game requirements is summarized in the second section. Section III presents the model assessment by area of consideration for the four models selected for detailed review: DIVWAG, ICOR, TAC ASSESSOR, and VECTOR-2. The last section contains a summary of the model assessments and a recommendation with rationale.

Overall Model Requirements Hierarchy

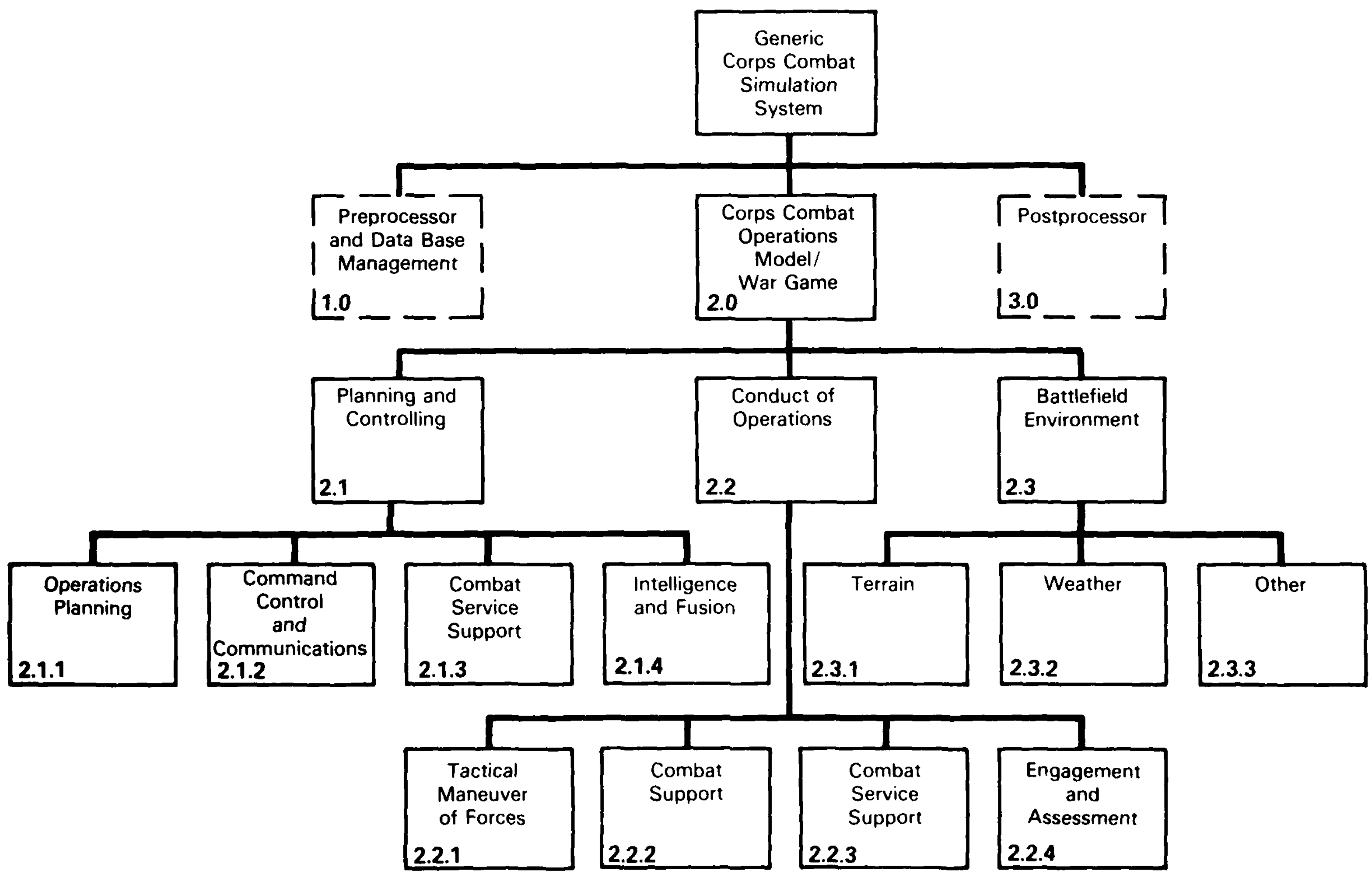

FIGURE 1. OVERALL MODEL REQUIREMENTS HIERARCHY

SECTION II

SUMMARY OF MODEL/WAR GAME REQUIREMENTS

2-1 GENERAL.

This section summarizes the statement of model/war game requirements utilized in the model/war game review and assessment for each of the eleven areas of consideration.

2-2 PREPROCESSOR AND DATA BASE MANAGEMENT.

This area of consideration includes efforts required to collect, preprocess, initialize, and maintain data. Preprocessing entails the data sources and their availability, any data transformations that are required, and verification of input data. The force structures, system performances, operational considerations, tactics, the scenario, and the environment must be determined and initialized. The level of effort involved in the data base preparation will depend upon the amount of preprocessing and initialization required. Maintenance of state and output variables must consider overhead, appropriate module/subroutine interface, and data required to support the planned analysis.

2-3 OPERATIONS PLANNING.

2-3.1 Processes.

Operations planning processes must include deployment and employment planning for:

- Combat forces

- Organic combat support
  - non-nuclear
  - nuclear (e.g., corps support weapon system (CSWS)/Lance, ADM)

- External combat support, e.g., TACAIR
  - non-nuclear
  - nuclear

The processes for operations requirements planning entail the combat forces, combat support (both organic and external) for non-nuclear and nuclear employment, and combat service support.

2-3.2 Essential Representation.

Realistic representation of those operational planning factors which strongly influence the course of battle, i.e., the threat, operations concept including situation dependent contingencies, resource allocation, task organization and important constraints given time available for planning, and force capabilities must be included in the model. Perceptions of the threat should consider the order of battle and force dispositions, capabilities, doctrinal procedures, and intentions. Mission definition and assignment involve the operational concept and task organization, control measures, and contingencies. The deployment and employment processes must consider the combat forces, conventional combat support forces, nuclear combat support forces, and survival measures. Influencing factors for operations planning entail the battlefield environment, time and resource constraints, and deployment and employment constraints.

2-4 COMMAND CONTROL AND COMMUNICATIONS (C^3).

2-4.1 Processes.

Communication processes must consider planning, operations, and message processing. The processes for command control must include friendly situation reporting, intelligence reporting, situation assessment, decision-making, and orders issuance. C^3 will encounter electronic warfare operations which affect friendly situations and intelligence reporting and planning and conducting electronic countermeasure (ECM) operations.

2-4.2 Essential Representation.

Explicit representation of C^3 to support the evaluation of alternative command control (C^2) procedures under conditions which represent the significant command elements and communication vulnerabilities are required to evaluate particular EEA. The command element hierarchy must be represented from battalion through corps and should include tactical, main, and alternate command posts and skip echelon and echelon bypass* capabilities. C^3 situation assessment must entail both friendly situation (FRENSIT) and enemy situation (ENSIT) delays, errors, and voids and include assessment logic. Decision-making should be doctrinal by echelon, should permit a conveyance of orders, and reflect timelines as a result. Communications must include representation for planning and allocation of capabilities, operations profiles (e.g., displacement, reliability), alternate procedures, and message processing delays. Influencing factors on C^3 should account for intercept profiles, jamming profiles, electromagnetic pulse (EMP) effects and vulnerabilities, and other significant command element vulnerabilities.

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*For the purpose of this study, these terms are defined as follows: skip echelon - processing requests and orders without going through all command echelons. Skipped echelons are provided with information concerning requests or orders but are not required or expected to staff and modify or comment on them. Skipped echelons may comment when circumstances warrant. Echelon bypass - processing requests or orders without going through all echelons because some echelon is destroyed, ineffective, or out of communication.

2-5 COMBAT SERVICE SUPPORT PLANNING.

2-5.1 Processes.

Essential resupply planning should include operations guidance and plans, requirements projections (supplies and transport), stockage status, CSS unit status, and transportation status. The finalized EEA focus on Classes I, III, and V of supply only. This does not imply that the planning and provision of medical treatment and evacuation planning, essential maintenance planning, transport support planning, and other CSS planning, e.g., decontamination, are of lesser importance. Study resource considerations narrowed the scope.

2-5.2 Essential Representation.

CSS planning is the determination of essential CSS requirements in the likely scenarios and evaluation of alternate procedures for providing the essentials. Essential representation includes anticipated consumption and loss rates, status reporting and requisition standard operating procedures, anticipated resupply rates, and operationally based allocations. Influencing factors are the battlefield environment, CSS unit status, i.e., supply and transport, and CSS vulnerabilities.

2-6 INTELLIGENCE AND FUSION.

2-6.1 Processes.

The processes for intelligence and the fusion of information are collection, control, processing, and dissemination. Collection of intelligence information entails representation of intelligence preparation of the battlefield, the essential elements of information (EEI) and other intelligence requirements (OIR), and the available means, i.e., sensors, human intelligence (HUMINT), higher level sources, and unit reports. To control the intelligence efforts, there must be collection management and mission management. Processing the information involves sorting and collecting, data base maintenance, fusion operations, and production of estimates and summaries.

Dissemination of target information and estimates and summaries must also be represented.

2-6.2 Essential Representation.

Sensor operational profiles; sensor performance parameters; CEWI Operations Center duties, to include sorting and collating, sensor tasks, analysis, and production and dissemination; and TOC tasks for fusion to situation assessment and intelligence mission management are the main factors for essential representation of intelligence and fusion. Influencing factors which should be represented in the model/war game are the battlefield environment, EMP effects and vulnerabilities, and other significant vulnerabilities such as deception, jamming, and combat losses.

2-7 TACTICAL MANEUVER OF FORCES.

2-7.1 Processes.

The movement, control, and survival of combat forces are the primary processes for the tactical maneuver of forces. Movement of combat forces involves both initial deployments and tactical redeployments. Control of combat forces for the corps depends upon the mission and objectives, task organization, related control measures, fire support operations, and reconnaissance operations. Control of combat forces for the division are similar to that of the corps. For the brigade and battalion, the control of combat forces should account for mission and objectives, task organization, related control measures, fire support operations, and engagement tactics. The survival of combat forces process is affected by movement, tactical disposition choices, and OPSEC measures.

2-7.2 Essential Representation.

A capability is needed providing considerable flexibility in representing a wide range of tactical choices for integrating the employment of combat forces in exploitation of tactical nuclear strikes. The fidelity of representation must be considered for engagement opportunities and assessments, movement rates and paths, unit formations and dispersions, C^2 measures, combat support, CSS, intelligence support, and maneuver unit/element resolution.

The main factors for essential representation of the tactical maneuver of forces can be divided into battlefield parameters and unit parameters. Battlefield parameters should include exposure profiles, engagement opportunity profiles, movement rates, key terrain, avenues of approach, etc. The unit parameters should account for dispositions of the company, the command element, individual sensors, TACAIR flights, attack helicopter platoons, the air defense fire unit, and supply point resolution. Also included in the unit parameters are mission and objective assignments, identifiable task organizations, major control measures specifications, combat support allocations, engaged unit tactical rules, and CSS status. Influencing factors which must be considered are the battlefield environment, engagement type possibilities, C^2 capabilities and vulnerabilities, and tactical constraints.

2-8 COMBAT SUPPORT OPERATIONS.

2-8.1 Processes.

The fire support planning process must consider conventional, nuclear, and chemical operations and the integration of these operations. Fire support operations depend upon target acquisition and target selection. Reconnaissance operations processes include national, TACAIR, and ground operations. Other combat support operations processes include close air support (CAS) operations, attack helicopter operations, air defense operations, and the planning and employment of ADM.

2-8.2 Essential Representation.

As with the tactical maneuver of forces, a flexible capability to represent a range of employment doctrines for combat support operations is required. Main factors that should be represented are target priorities, acquired target lists, target dwell and delay times, and weapon-target allocations rules. Employment doctrine, rules, and constraints should be included for conventional fires, chemical fires, air defense fires, reconnaissance operations, attack helicopter operations, CAS, and combat engineer operations. Nuclear employment doctrine should consider damage assurance criteria and rules; preclusion analysis and collateral damage constraints; radiation, fallout predictions, and effects; blast and fire predictions and effects; and deconfliction procedures and warning. Influencing factors for combat support operations are the battlefield environment and the opposing forces' status.

2-9 COMBAT SERVICE SUPPORT OPERATIONS.

2-9.1 Processes.

Processes for CSS operations include essential resupply operations for Classes I, III, and V of supply. Other CSS operations are the remaining supply classes, medical treatment and evacuation, essential maintenance, transportation, decontamination, and field services (i.e., replacements, graves registration, finance, etc.).

2-9.2 Essential Representation.

The essential representation for CSS operations entails operational representation of those operations specified in the CSS planning requirements. Main factors for support unit parameters should include the status, i.e., consumption and losses, any requirements, the operationally based priorities, and the locations. Supporting parameters should account for support unit locations, stockages, and transport capabilities. Influencing factors that should be accounted for and affect CSS operations are the battlefield environment, processing and transport times, and vulnerabilities.

2-10 ENGAGEMENT AND ASSESSMENT.

2-10-1 Processes.

Weapon-target allocations, weapon-target engagement, and engagement outcomes are the processes for engagement and assessment. Detection and identification, engagement doctrine and rules, and acquisition are included in the weapon-target allocations process. The weapon-target engagement process accounts for the acquisition to engagement cycle and tactical assessment. The engagement outcome process reflects actual lethality determination, tactical damage assessment, and reengagement doctrine and rules.

2-10.2 Essential Representation.

A standard set of requirements for essential representation of engagement and assessment are generally well simulated in most models. The criteria of concern here are mostly for investigating tactical doctrine and those related to the influencing factors as they combine to influence tactical choices based upon current situational conditions. Main factors which should be represented are detection and identification processes, engagement decision and request for fire if appropriate, munition status, engagement doctrine, acquisition, engagement, actual lethality calculation, and tactical damage assessment. Influencing factors entail mission and tactical rules, battlefield environment, perceived tactical situation, and opposing forces status.

2-11 BATTLEFIELD ENVIRONMENT.

2-11.1 Processes.

Battlefield environment processes are terrain, e.g., line of sight, trafficability, obstacles; weather, i.e., visibility, day/night and moon cycle, cloud cover, trafficability; and other processes such as battle-induced obscuration, battle-induced obstacles, and electromagnetic influences.

2-11.2 Essential Representation.

The main concern is representing the principle influencing factors: the effects of terrain, weather, and battle-induced environmental aspect, e.g., obstacles, fallout, EMP on the major factors tested. Essential representation for the battlefield environment should take into account combat system availabilities, detection distribution, engagement distribution, engagement effectiveness, movement rates, C^3 capabilities, and resupply capabilities.

2-12 POSTPROCESSOR.

The level of effort and comprehensiveness for supporting the analysis in an orderly and complete manner was considered in evaluating the last area of consideration: the model postprocessor. Postprocessor concerns included analysis plan requirements, i.e., EEA, measures of effectiveness (MOE), and formats; interfaces with the model source program; extraction processes; sort/merge requirements; and report generator requirements - printed outputs, plotted outputs, and special analytic procedures, e.g., estimations, MOE distributions. Postprocessor evaluation finally regarded completeness of battle history data, ease of access and manipulation, and ease of accomplishing analysis.

SECTION III

MODEL ASSESSMENT BY REQUIREMENT AREA OF CONSIDERATION

3-1 GENERAL.

An extensive search was conducted to identify the model(s)/war game(s) that would meet the criteria set forth in the statement of model/war game requirements. Those model(s)/war game(s) reviewed and considered as candidates for recommendation included CHEMCEM, COMMO III, CORDIVEM, DIVWAG, FEWTS, FOFEBA study models and methodologies, ICOR, IDAGAM, JANUS, JIFFY III, the McClintic Theater Model, NURAC '84, NUFAM II/III, SAVAGE, TAC ASSESSOR, TACWAR, TALON, TIWES, and VECTOR-2. Any model/war game whose basic characteristics/attributes were similar to (or would be similar to in time for the model/war game enhancement phase) the statement of model/war game specifications was chosen for in-depth analysis.

Four models were selected for extensive review:

- DIVWAG
- ICOR
- TAC ASSESSOR
- VECTOR-2

All four models were assessed via their current state of documentation and their strengths, weaknesses, and enhancement requirements were determined for each area of consideration. The remainder of this section presents the results of each model analyzed (in alphabetical order) for each of the eleven requirement areas of consideration.

3-2 PREPROCESSOR AND DATA BASE MANAGEMENT.

3-2.1 DIVWAG.

The Division War Game Model (DIVWAG) is a division level, period-based war game with modular load programs and "operations oriented input language" (DIVWAG source language). To change military organizational structures and the level of unit resolution within the course of a game, DIVWAG uses a resolution/nonresolution unit feature. The war game is conducted with the resolution units and nonresolution units are used for bookkeeping purposes. At any time during game play, the gamers can combine several resolution units into one larger unit, thus lowering the degree of unit resolution; or decompose a resolution unit into smaller subunits, thus raising the degree of unit resolution. DIVWAG is currently inactive, however, all necessary programs and files for execution are in existence.

DIVWAG is division level only; processes only have a batch processing capability and the model requires laborous data base verification. Extensive enhancements are required of the resolution/nonresolution unit feature to develop a corps level model and DIVWAG should be enhanced to permit interactive use at any organizational level.

3-2.2 ICOR.

The Integrated Corps (ICOR) model is essentially a period-based war game that has corps level representation with modular load programs and batch and terminal data input capabilities. Combat aircraft, air defense, nuclear munitions, radars and sensors have provisions for specifying a particular type of asset within a class.

Extensive analysis and preprocessing is required to validate direct fire rates including air defense attrition values and artillery and area fire air munitions fractional damage factors. ICOR model logic does not accept basic weapons performance parameters and condition these with major environmental factors in the calculation of attrition rates; thus the entire burden of scenario dependency is placed on the analyst preparing the data base. Enhancements are required for interactive use of ICOR at any organizational level above brigade. No improvements are needed for batch operation at corps level given extensive input preparation between periods.

3-2.3 TAC ASSESSOR.

TAC ASSESSOR is a highly modular, computerized, corps level, combined arms simulation model with batch and interactive processing that maintains input and state variables. Dynamic storage allocation permits the storage and handling of data and any component of the data base can be located, used, redefined, or expanded. TAC ASSESSOR modules operate on input defining the contents of the various prototype datasets and provide a programmer's notebook formatted and accompanied by English language descriptors to serve as documentation of the data base organization. TAC ASSESSOR is a heavily data-dependent model requiring much time and care in preparing, modifying, and verifying the input data and data base. Locating data errors is extremely difficult due to the amount and complexity of data and that the model only checks for syntax.

3-2.4 VECTOR-2.

VECTOR-2 represents the activities of Army and Air Force units of two opposing forces in a conventional, theater level, mid-intensity ground and air campaign with battalion level resolution to provide information useful in making net assessments, in general purpose force tradeoff analysis, and in studies of strategies and tactics. VECTOR-2's Data Preprocessor prepares data inputs and the Binary Formatter converts inputs into binary mode for efficiency. The Program Change Monitor facilitates modification of existing variables or addition of new variables. Though designed as a theater level model, VECTOR-2 can also be used to simulate combat at the corps or division level. VECTOR-2 maintains state and output variables, has interactive and batch processing capabilities, and contains software to assist in verification as advisory lists of messages help the user understand the full impact of the proposed changes, appropriate revisions to the code, and updated descriptive files. VECTOR-2 requires data to describe the quantitative performance capabilities of the forces, weapons systems, and other resources; initial force and supply inventory data; data describing the environment (terrain and weather); the tactical decision rules; and initial intelligence information.

3-3 OPERATIONS PLANNING.

3-3.1 DIVWAG.

The Creative Processing Submodel determines the time delay for each processing of a report and for each decision-making sequence. The Decision Submodel simulates certain decisions concerning the routing, use, or application of the intelligence collected and processed and mainly concerns two areas: information/intelligence flow and fire support coordination. The Creative Processing and Decision Submodels provide representation of threat perception to the limit of dispositions portrayed and mission definition and assignment for TACAIR, attack helicopter, and artillery (conventional fires only). The Intelligence and Control Model interacts directly or indirectly with most of the combat activity submodels of the DIVWAG system and interfaces with these various models to schedule, execute, and respond to automatic firepower events during the dynamic period of the game. The Automatic Event feature for various resolution unit activities permit artillery fire and TACAIR mission assignment and scheduling, and engineering task assignment and scheduling.

DIVWAG does not represent tactical nuclear planning, i.e., all nuclear planning activities are manual and must occur between simulated periods. TACAIR is not fully representative of the NATO system in that no methodology exists for army group TACAIR and corps level activities. DIVWAG requires extension of the Creative Processing and Decision Submodels to represent higher level planning of TACAIR employment.

3-3.2 ICOR.

All applications of ICOR are accomplished by man-in-the-loop, i.e., inputting orders to simulated units at periodic intervals during the game. A well defined protocol for initial and between period operations planning permits the user to organize, deploy, and task the allocated forces such that the objective specified by higher command echelons are accomplished within the constraints imposed by the scenario and force characteristics. ICOR's Operation Reaction System uses the current unit situation and mission codes to look up the unit action code; gets an interim operation code for determining the parameters affecting combat, movement, and situation evaluation for the next cycle of the physical process; and finally, mission transition, yields a new mission code. The TACAIR logic is adaptable to the NATO planning system.

All decision-making and essential planning above battalion level require massive man-in-the-loop efforts. Enhancement requirement: the embodiment of selected lower level planning activities into ICOR logic, i.e., artillery fire planning and prompted air reconnaissance planning.

3-3.3 TAC ASSESSOR.

The TAC ASSESSOR model is event-based whose emphasis is on ground/ground and air/ground tactical interactions with no air/air interactions being simulated. Action sequence chains connect several elementary events by causality. Operations planning entails

- Command perception from reports generated by intelligence, operations, and logistics staffs

- Situation assessment whereby the commander decides if the situation is proceeding towards that anticipated by the plan via directed relational graphs of the battlefield scene

- Mission planning which translates the commander's course of action into orders to subordinate units from developed alternative mission assignments using a tree structure

- Plan evaluation whereby the likelihood of success or failure of a tentative plan is determined to include predicting possible outcomes, evaluating contingency plans, and then, choosing a plan

- Each commander's assessment of the situation which is based on time, sufficiency of data, force losses, and the success or failure of the assigned mission.

Operations planning is accomplished within time, resource, employment, and deployment constraints. TAC ASSESSOR model logic is for operations at corps level and below, and all operations planning is from corps headquarters and down. TACAIR planning is not fully representative of the NATO system and TAC ASSESSOR should be so enhanced. Air-to-air operations should also be included in any enhancement effort. TAC ASSESSOR contains no logic for nuclear and chemical operations planning thus requiring model processes and artificial intelligence techniques enhancements.

3-3.4 VECTOR-2.

All operations planning and contingencies for theater to battalion (or corps to company) level are defined and implemented through VECTOR-2's tactical decision rules. Friendly and enemy desired, perceived, and actual states of the world are represented by state variables and are updated for tactical decisions. Commanders assign missions and allocate resources given a desired and perceived state of the world. TACAIR is representative of the NATO system. Although VECTOR-2 is designed to represent conventional warfare, nuclear and chemical deployment procedures can be implemented by altering the tactical decision rule logic to reflect the use of nuclear and chemical weapons. A lot of time and care must be given to the development, structuring, and inputting of the tactical decision rules so that user desired plans and contingencies are properly represented.

3-4 COMMAND CONTROL AND COMMUNICATIONS.

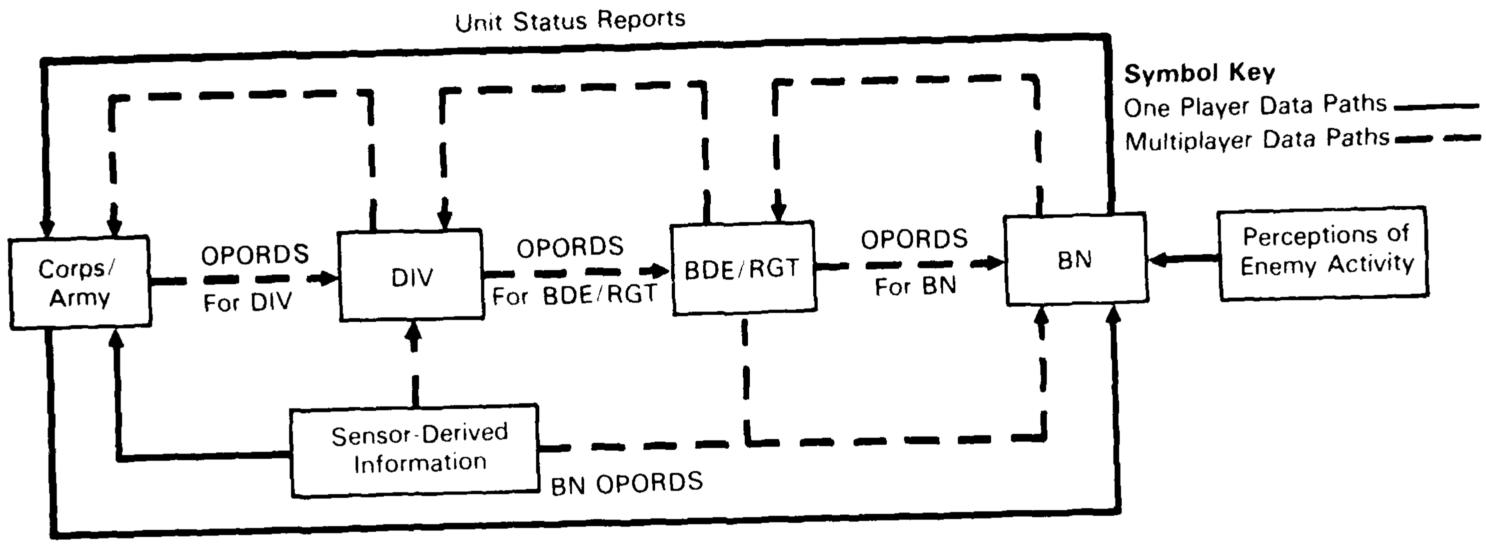
3-4.1 DIVWAG.

C^3 activities are closely interfaced with processing and decision submodels. Automatic events logic for eleven resolution unit C^3I activities is closely interfaced with the Creative Processing and Decision Submodels. The Creative Processing Submodel and period intelligence reports provide a good representation of situation assessment, however, message volume, capacity, and queuing are not represented. DIVWAG does not represent command element vulnerabilities to intercept, jamming, and EMP and representation of attack by fire is inadequate for analysis purposes. Queuing effects of variable stress on the C^3 system and representation of command element and communication vulnerabilities are DIVWAG enhancement requirements.

3-4.2 ICOR.

Initial unit data are translated into orders through the C^2I process. Control of units while executing the initial plan and throughout game play is accomplished by man-in-the-loop. ICOR contains a well defined protocol for man-in-the-loop representation of the C^2I processes. Figure 2 is an overview of the ICOR C^2I processes from an echelon standpoint and Figure 3 expands this process to differentiate between those steps required prior to initiating play and those required during play.

The scope of the C^2 hierarchy in ICOR is from division or corps through battalion headquarters. All C^2 functions and decision-making above battalion level are primarily simulated by man-in-the-loop. ICOR contains no explicit representation of communications except for sensor operations, situation reporting, and operation order delay times. A communications submodel is required with adequate representation of operations procedures/ profiles and vulnerabilities. ICOR should contain a C^2 submodel for



Unit Type	OPORD Components	Status Report Components
1. Maneuver Units:	Mission, Objectives, Axis, Resources, Execution Time	Locations, Movement Directions and Speeds, Resources, Opposition, Suppression
2. Fire Support Units: (Artillery, Air, and Air Defense)	Mission, Targets, Move Objectives, Axis, Resources, Execution Time	Same
3. Logistics Units:	Mission, Move Objectives, Axis, Resources, Execution Time	Same

When one Person Plays the Role of All Echelons He Must Base His Orders on Only the Portion of the Total Data Available to His Side that Could Reasonably be Expected to be Available to the C^2I Echelon Likely to Give Those Orders at that Time

FIGURE 2. OVERVIEW OF ICOR COMMAND CONTROL AND INTELLIGENCE (C^2I) PROCESSES

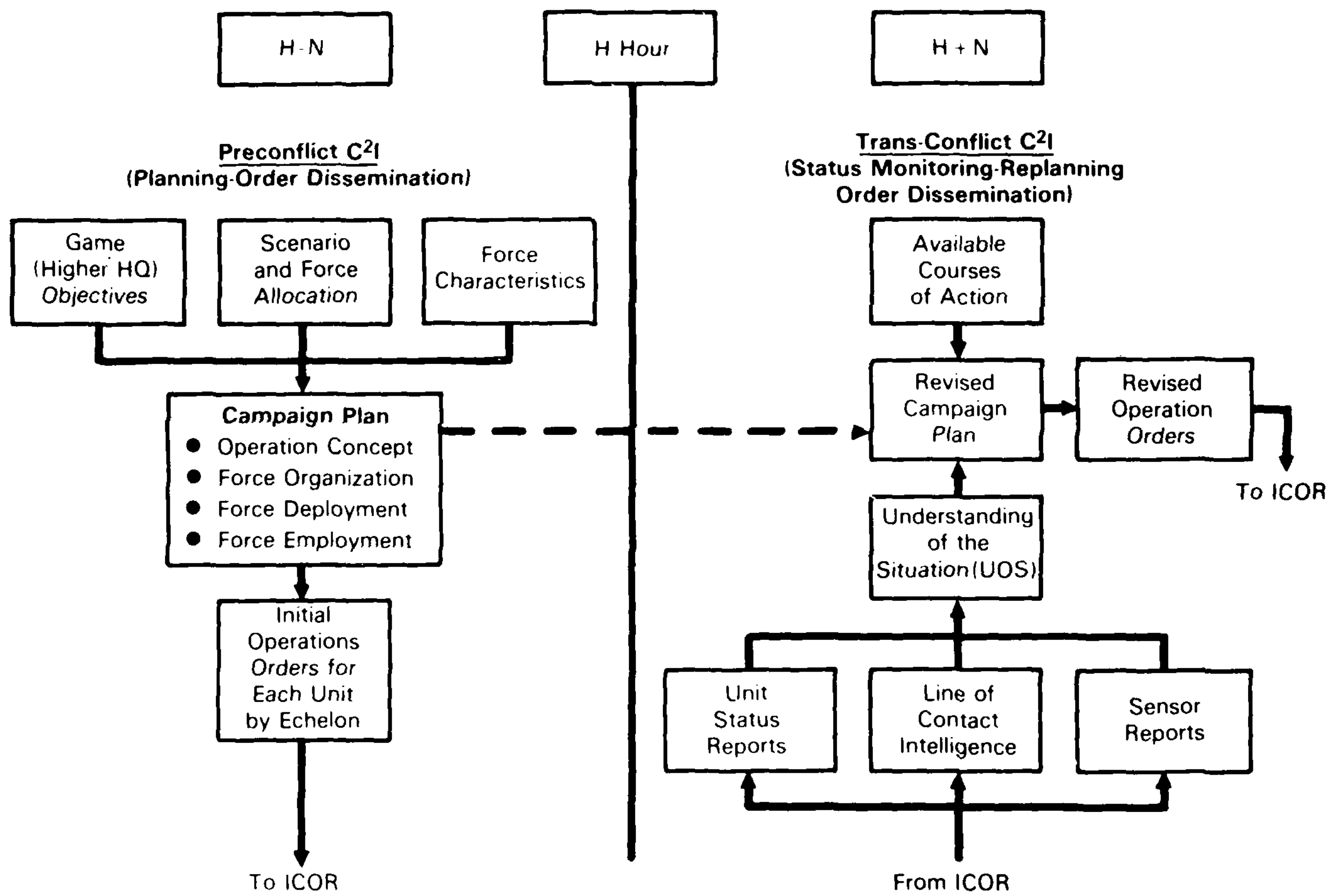


FIGURE 3. DATA FLOW FOR ICOR C^2I PROCESSES

selected division and brigade level situation assessment, decision-making, and orders issuance activities.

3-4.3 TAC ASSESSOR.

C^3I activities in TAC ASSESSOR are modeled in great detail, and the decision processes of individual commanders and their staffs are simulated by advanced artificial intelligence techniques. The command decisions are based on each individual's "perception" of the status and disposition of local forces, formed and updated independently at each headquarters via messages sent over a communications network. Each commander's assessment of the battlefield situation is individually maintained and the perception of the local situation and the incompleteness of that situation is represented. The communications module accepts messages and delivers them to appropriate receiving units at the appropriate times via direct handover, landline, or radio broadcast. Facility-loading, jamming, garbling, and relaying are simulated as is C^3 processing and decision-making for air missions. Skip echelon and echelon bypass capabilities and EMP effects are required enhancements for TAC ASSESSOR.

3-4.4 VECTOR-2.

The tactical decision rules, as a collection, may be regarded as the core of VECTOR-2's representation of the C^2 function and are used to govern:

- Mission assignment, force deployment, and organization for combat
- Air mission planning
- Fire support allocation and mission planning
- Air mission and maneuver unit situation assessment and mission response
- Construction, repair, etc.

The user can represent alternative views as all rules can be changed or modified. Intelligence and C^2 are transmitted via a communications process (resulting in a possible time lag or delay) and are eventually carried out in such a way as to affect combat and related processes. These processes affect the actual state of the world by changing force levels and deployments for both forces. The command element hierarchy can represent company through corps level and desired, perceived, and actual states of the world to permit C^3 processes to function at all organizational levels.

VECTOR-2 does not represent EMP effects and communications degradation is not modeled. Only a vertical command element hierarchy exists whereby a unit receives its commands from and provides feedback to one and only one commanding unit. Theater Force Evaluation by Combat Simulation (TFECS) is a theater level methodology for quantifying the contributions of C^3I, EW to the ability of a theater force to attain its objectives. This methodology was designed for incorporation into the VECTOR-2 model and would correct deficiencies in the VECTOR-2 C^3I, EW logic.

3-5 COMBAT SERVICE SUPPORT PLANNING.

3-5.1 DIVWAG.

The DIVWAG Combat Service Support Model simulates personnel replacement, resupply of critical consumables and expendables, and resupply of major end items. The resupply or replacement process is treated in three essential areas: ordering, distributing, and receiving supplies. The process of ordering supplies requires the determination of the quantity to order (based on projected usage), when to order (dependent upon projected usage and reorder cycle time), and the priority of order (dictated by the mission of the using unit and the criticality of the supplies to that mission). DIVWAG contains projected usage calculations for Classes I, III, V, and VII of supply, transportation-assignment logic for resupply operations, and priorities logic for allocation of supply shortfalls. CSS planning modelling deficiencies are similar to those for CSS operations and these and the appropriate enhancement requirements are discussed in paragraph 3-9.1.

3-5.2 ICOR.

CSS planning is not represented in ICOR. A CSS planning submodel containing the processes and essential representations outlined in the statement of model/war game requirements is required.

3-5.3 TAC ASSESSOR.

Similar to ICOR, CSS planning is not represented so TAC ASSESSOR requires logic for the processes and essential representations outlined in the statement of model/war game requirements.

3-5.4 VECTOR-2.

The tactical decision rules govern all resource allocations and distributions to appropriate groups and the effects of constrained supply levels on combat activities. VECTOR-2 does represent unit resupply activities and tallies the quantity of supplies consumed or destroyed and updates inventories accordingly. VECTOR-2 does not explicitly represent logistical vehicles, routes, and route capacities and the processing and transport of supplies. The supply logic developed for TFECS would reduce the enhancement requirements for CSS planning, when incorporated into VECTOR-2.

3-6 INTELLIGENCE AND FUSION.

3-6.1 DIVWAG.

The Intelligence and Control Model simulates the following military activities:

- Sensing and reporting of target elements
- Time delays for collection, analysis, routing, and decision-making
- Development of targets for fire missions

- Intelligence analysis and maintenance of intelligence files

- Decisions on information/intelligence flow and requests for fire support

- Flow of information/intelligence between analysis points

- *Contents of periodic division intelligence* summary.

DIVWAG contains well defined interfaces among Air Reconnaissance, Ground Collection, Creative Processing, and Decision Submodels and Area Fire, Air/Ground, Movement, Ground Combat, and Intelligence and Control Models. The CEWI Operations Center is simulated in the Creative Processing Submodel and TOC operations for situation assessment are modeled in the Decision Submodel. Not all sensors needed are currently represented so DIVWAG requires an updating of its sensor representation. The effects of EMP, deception, and jamming are not modeled, therefore, logic for these vulnerabilities must be appropriately appended to the DIVWAG system.

3-6.2 ICOR.

ICOR extensively and explicitly simulates sensor system operations and the intelligence process. The physical processes of sensor operation are modeled in an automated fashion, while sensor tasking (dependent on sensor type) is either partially automated or implemented by the man-in-the-loop commander. The five primary elements of sensor system operations considered are:

- Sensor system tasking

- Sensor deployment (ground or aerial platform)

- Target detection capability

- Target discrimination capability

- Sensor system reporting.

The actual sensors simulated include both current and developmental, imaging and signal intelligence (SIGINT) systems; needed sensor systems are represented. Imaging information that can be obtained from a detection is a function of the sensor system and the target array used. The man-in-the-loop tasks each system individually, identifying mission time and duration, flight path, radar or camera orientation, and "swath range" (if a system variable). Even though sensor performance is modeled, all sensor tasking (collection management) occurs either at initialization or by man-in-the-loop and all CEWI and TOC operations occur between periods via man-in-the-loop assessment of sensor/intelligence reports. ICOR enhancement requirements include realistic and timely representation of the CEWI Operations Center, the TOC, and vulnerabilities to EMP and deception.

3-6.3 TAC ASSESSOR.

"Action" units interact with the intelligence and command structure by means of a special headquarters unit, the action unit headquarters, colocated with the action unit, and permitted to retrieve exact and accurate data about the action unit's current location and condition, attrition suffered, etc. All other elements of the command control structure (e.g., higher headquarters) must obtain information from the action unit headquarters through the communications system by means of message traffic. Therefore, action unit headquarters accept messages, initiate action, and generate messages. Other headquarters, those associated with a unit higher than an action unit (brigade, division, corps, etc.), are responsible for making complex decisions.

"Perception vectors" reflect uncertainties as to both friendly and enemy, forces and intentions, and only receipt of data brought direct from sensoring mechanisms or via the C^3I system is allowed to alter this perception. Each target and perceived element are compared by means of a signature table which examines target and perceived element type, location, and velocity and a match is declared if the score produced by the signature table is greater than a threshold value, in which case the data sets are merged. Whether or not a particular item of information is used in the merging depends on the time of the data and the uncertainty in the data. Perceived elements can also be "lost" if no new data about the element has been received within a specified length of time, the element has been reported "dead" or "killed", or if an element expected to appear in an area within the field of view of a particular sensor did not do so. Headquarters can request additional reconnaissance missions if more information is required. The communications module simulates the effects of facility-loading, jamming, garbling, and relaying, however, EMP effects and deception are not represented. TOC activities are limited to the corps level and CEWI operations are not modeled. Vulnerabilities to EMP and deception and CEWI Operations Center and expanded TOC activities must be added to TAC ASSESSOR.

3-6.4 VECTOR-2.

The commander's perception of the enemy and the area of operations is represented in VECTOR-2 by a set of state variables describing the current state of knowledge about future weather conditions, potential targets, and the enemy's order of battle. Weather intelligence is in the form of five-day forecasts by both friendly and threat of future weather trafficability and visibility indices. Target intelligence is in the form of lists of targets against which fire support may be allocated. Kinds of targets which may be acquired include front-line maneuver units, field artillery batteries, air defense artillery sites, command post supply depots, uncommitted maneuver unit reserves, committed maneuver unit reserves in transit, penetrating aircraft groups, aircraft and helicopter bases, and target acquisition resources. Order of battle intelligence consists of current estimates of the strengths of enemy maneuver units (both front-line and reserve) by coordinates, numbers of other resource groups by zone, and number of enemy aircraft operating in each sector.

Intelligence and target acquisition processes collect information about future weather conditions, potential targets, and the enemy order of battle for use in fire support allocation and C^2 processes. Tactical decision rules manage intelligence at all levels and fourteen classes of sensors collect target and order of battle intelligence. Previous information is combined with sensor target detections to form and update state of the world perceptions.

The effect of communications in VECTOR-2 is represented by the expected value of the delay incurred in transmitting messages associated with tactical decisions. Communication delays are represented at all levels from battalion up to corps (or equivalent). Higher level delays are omitted under the assumption that they are an insignificant portion of the total time to perform a command control function. The service characteristics of the communication system are not subject to change by attrition or EW (which is not represented in VECTOR-2). The communications system can be decoupled; i.e., the transmission of a message from origin to destination can be considered to be independent of any other network structure and status. Incorporating the TFECS C^3I, EW logic into VECTOR-2 would eliminate these assumptions and the model would adhere to the criteria set forth in the statement of model requirements.

3-7 TACTICAL MANEUVER OF FORCES

3-7.1 DIVWAG.

The DIVWAG Movement Model repositions military units about the battlefield by considering characteristic administrative or tactical movement rates for the type of unit to be moved; the effects of barriers and facilities that may tend to impede or improve the unit's movement capability; the effects of variations in terrain, weather, and light conditions on the unit's movement capability; and the availability of fuel. Tactical and administrative movement of units by ground or air in the Movement Model is usually in response to gamer-planned DIVWAG source language (DSL) orders. The gamer must plan, coordinate, and schedule all movement performed by this model through a flexible file structure for representing and altering task organization of forces, except that controlled by the Engineer Model which relocates engineer units. Unit capabilities are properly affected by CSS status and unit and element resolutions adhere to the statement of model requirements criteria for scenarios up to division level.

Movements of units not in direct response to gamer input orders are accomplished within other models of the DIVWAG system. The Ground Combat Model moves maneuver units while they are engaged in combat, the CSS Model controls logistics movements, and the Air Ground Engagement Model accomplishes the movement of air units when this movement is in response to automatically generated missions. The reconnaissance portion of the Intelligence and Control Model regulates the movement of reconnaissance units and subunits.

Unit mission choices are entirely DSL order dependent so logic to represent unit mission and activity dependencies on unit operational stati needs to be added to the DIVWAG system. C^2 capabilities and vulnerabilities representation embodies only the effects of time delays, therefore, logic to represent the reduced effectiveness or loss of C^2 capabilities should be appended to the DIVWAG system.

3-7.2 ICOR.

ICOR's Operation Reaction System concept for assignment of operation codes based on mission codes and situation parameters affords flexibility in specifying alternative maneuver doctrines. The ICOR model employs a hexagonal coordinate system for locating units on the battlefield. The hexes can be nested or clustered in groups of seven to make larger hexagons thus permitting considerable flexibility in specifying tactical maneuver schemes. Unit and element resolutions adhere to the statement of model requirements criteria for corps level scenarios. All unit movement is assigned via man-in-the-loop and each unit weighs its decision on how to move toward the objective stated in the unit's operations order. Weighing factors include terrain trafficability, cover, and road structure; relative massing of forces; perceived location of threat forces; and organizational cohesiveness. These weighing factors and other parameters affecting the unit's operation are determined by the unit's operation code, also contained in its operation order. A unit's mission code is what the unit is ordered to do; a unit's operation code is what the unit is forced to do under the circumstances.

Unit capabilities are affected only by Class V status and C^2 capabilities and vulnerabilities representation embodies only the effects of time delays, i.e., C^2 is essentially invulnerable. Logic to represent the effects of CSS status on combat capabilities and the reduced effectiveness or loss of C^2 capabilities should be added to the ICOR model.

3-7.3 TAC ASSESSOR.

Unit motion is along a prescribed path, which is attached to the individual military unit dataset in the form of a list of path points. If no such list is present, the unit remains motionless until such a list is provided by either manual intervention or by the activities of a command decision module. The speed of a unit is a function of the unit's basic velocity (prescribed for both day and night) and combat, terrain, and suppressive factors. Units are provided with mission and role assignments from headquarters units. TAC ASSESSOR permits combat support allocations via requests from corps headquarters or from corps and barrier headquarters for immediate support.

C^2 capabilities and vulnerabilities and CSS do not affect unit maneuver in TAC ASSESSOR and exposure profiles are not modeled. Logic to represent the effects of C^2 capabilities and vulnerabilities, CSS status, and exposure profiles should be incorporated into TAC ASSESSOR.

3-7.4 VECTOR-2.

VECTOR-2 explicitly represents air flight and maneuver unit movement. The initiation of movement is governed by tactical decision rules (possibly delayed by communications and decision lags). Given such a decision for a front-line or reserve maneuver unit, input movement rates (which are a function of combat activity, type of terrain, and unit composition) are used to represent the travel of the unit from its origin to its destination. Similar rates are used to represent the movement of flights of attack or interceptor aircraft from their airbase or loitering position to their target and back at the end of the mission.

Movement of forces on the ground in VECTOR-2 is represented in varying levels of detail, depending on the type and level of the force and the activity in which the force is engaged. Reorganization movement of all forces, which may occur as frequently as once each model time period, is carried out instantaneously at the start of the period in which the reorganization takes place. Distant reorganizational moves of maneuver units (between sectors) have travel times associated with them during which the moving units are unavailable for combat. During these periods, the units are not tracked on (X,Y) coordinates, but they are subject to attrition.

Tactical movement of maneuver unit forces (such as the movement of a committed reserve or an unengaged front-line unit) is explicitly simulated. Scenario, movement, and line of sight data are used to calculate velocities and update unit positions on the battlefield. The movement of forces other than maneuver units (such as field artillery batteries, air defense units, and command posts) is implicitly represented by maintaining each such resource group at a fixed distance from the forward edge of the battle area (FEBA) (or, in the case of command posts, at a fixed depth behind the maneuver unit with which it is associated). VECTOR-2 explicitly simulates the movement of flights of attack, escort, and interceptor aircraft, and of attack helicopters performing a fire and support mission.

Movement processes interact with other portions of VECTOR-2 to:

- Produce changes in range between firers or sensors and their corresponding targets

- Result in delays in the effects of certain processes, such as commitment of a reserve unit or an air-to-ground attack

- Modify the behavior of maneuver units and the corresponding detectability and vulnerability of such units, both during direct fire engagements and for fire support acquisition and lethality.

FEBA movement coincides with front-line force movement rather than employing the firepower score-force ratio concept. Tactical decision rules identify task organizations, specify major controls, allocate combat support, and define effects of unit CSS status.

3-8 COMBAT SUPPORT OPERATIONS.

3-8.1 DIVWAG.

The Area Fire/TACFIRE Model represents the scheduling, delivery, and assessment of non-nuclear area fire munitions by cannon systems, missile systems, and multiple rocket launchers, and the assessment of mortar fires generated by the Ground Combat Model. The aspects modeled include the fire planning, target analysis, fire direction, and fire support coordination functions inherent in the employment of field artillery as well as the assessment of target damage resulting from the execution of the scheduled fire missions. The tactical fire direction and coordination capabilities of the division TACFIRE system are also represented within the model.

The Area Fire/TACFIRE Model consists of three submodels designed to represent the employment of area fire (cannons and missiles) conventional field artillery systems. These submodels are the DSL Fire Order Scheduling Submodel, the division's TACFIRE Scheduling Submodel, and the Delivery and Assessment Submodel. A macroflow of the relations among these submodels and between these submodels and other models and/or external DSL gamer control is shown in Figure 4.

DIVWAG models employment doctrine, rules, and constraints for conventional combat support, but not for chemical operations and precision guided munitions. No aspects of nuclear employment doctrine are represented and reconnaissance operations at the national level are not modeled. To fulfill the statement of model requirements criteria, DIVWAG needs logic to represent:

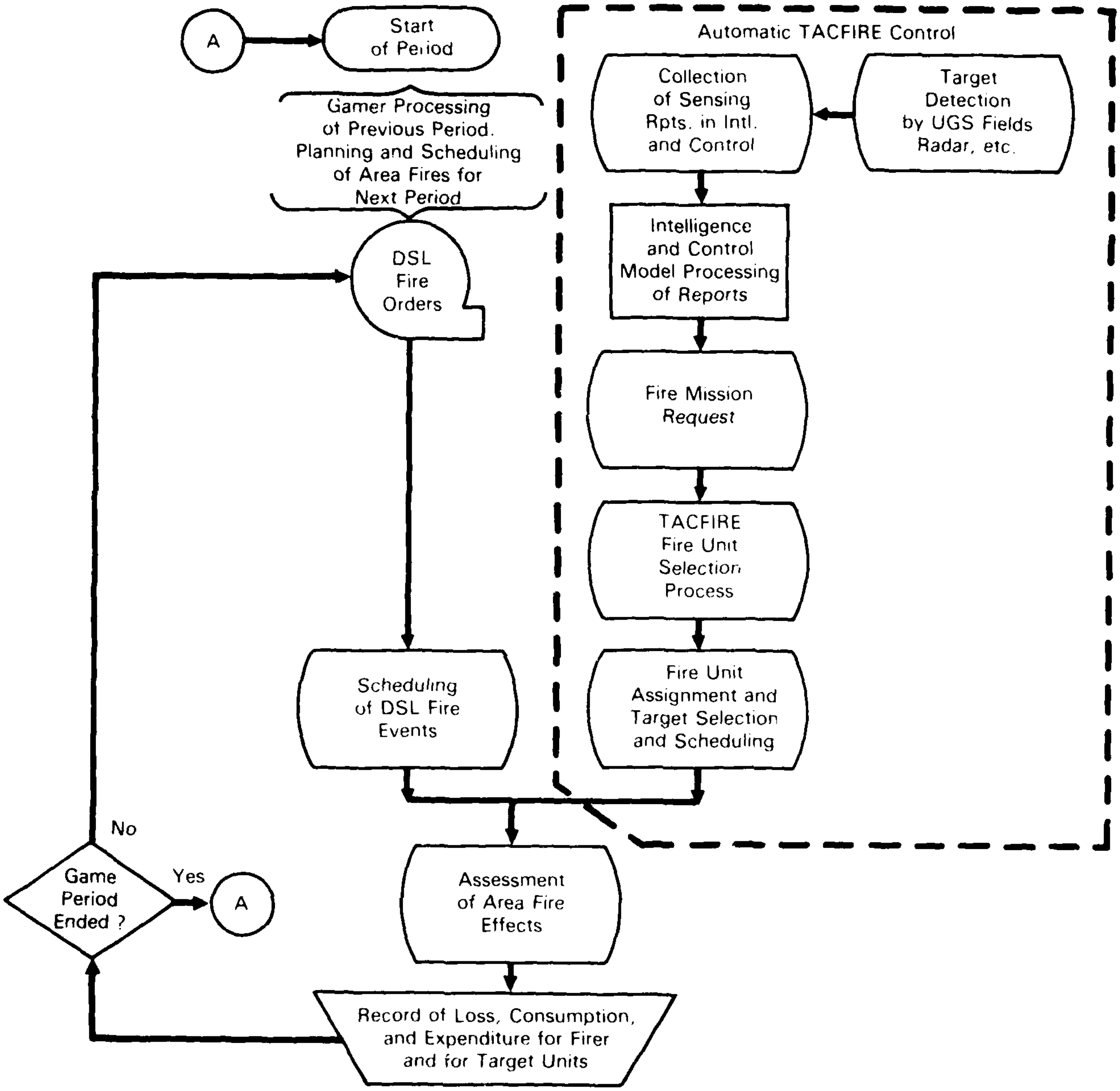


FIGURE 4. DIVWAG AREA FIRE/TACFIRE MODEL MACROFLOW

- Chemical warfare capabilities and operations

- Precision guided munitions

- Tactical nuclear means and employment doctrine

- National reconnaissance capabilities which can affect corps operations.

3-8.2 ICOR.

In ICOR artillery operations are modeled at the battalion level, the lowest unit typically treated in the simulation, except for the nondivisional armored cavalry squadrons, where the organic artillery batteries are explicitly played and located, and the multiple launch rocket systems which are modeled and explicitly represented at the platoon level. Even though the artillery firing unit itself is not explicitly represented, the effects of each battalion are modeled at the firing unit level. Missions include target servicing indirect fire, counterfire, interdiction, and suppression of enemy air defenses.

The ICOR air support operations modules feature two primary support missions: CAS and air interdiction. Various interdictions may be accomplished through the man-in-the-loop assignment of the air penetrators. The flights operate from a notional tactical air base, which generates CAS sorties and penetrator missions at a user specified rate commensurate with different aircraft launch rates. These missions are flown by any number of types of user specified aircraft. Each aircraft has time delays associated with rearming and refueling, thus influencing aircraft availability. Attack helicopters are played in a similar fashion, accounting for their unique employment and support characteristics. Aircraft are subject to attrition from air defenses as they fly their missions.

Conventional artillery, attack helicopter, and TACAIR capabilities and operations including air defense and an interface between sensor capabilities and conventional fires provided by artillery, attack helicopter, and TACAIR are modeled in ICOR. Chemical warfare capabilities and doctrine, combat engineering capabilities and doctrine, and reconnaissance operations at the national level are not represented in ICOR. Nuclear employment representation except for nuclear warhead resupply must be performed manually by man-in-the-loop. These deficiencies can be rectified by incorporating into ICOR logic to represent:

- Chemical warfare capabilities and doctrine
- Engineering capabilities and employment
- Tactical nuclear employment and doctrine
- National reconnaissance capabilities which can affect corps operations.

3-8.3 TAC ASSESSOR.

TAC ASSESSOR models artillery fire, air defense, and aircraft through unit roles and mission assignments. Artillery and aircraft can both suppress (i.e., slow down and decrease fire effectiveness) and destroy targets on the ground and affect ground unit movement and attrition. TAC ASSESSOR does not consider different effects for different artillery round types employed by the same unit and similarly the model assumes that all aircraft in a flight are the same type, have the same ordnance, and all fire at the same target. Aircraft are vulnerable to ground air defenses; TAC ASSESSOR models two types: organic air defenses (those weapons to be used against aircraft that are deployed with a maneuver unit) and autonomous air defenses (those weapons that are deployed on their own and protect specified areas). Air defense movement and location are controlled by headquarters and air defense can be degraded by jamming to reduce the effects of its detection radius. Aircraft allocations for reconnaissance, interdiction, CAS, air and ground alert, the air forward air controller, and defense suppression are represented.

The Air Decision Model portrays the TACAIR control system embodied in TAC ASSESSOR. Entities modeled include air request portions and control portions at the corps level and below. Mission requests come into the Air Decision Model from corps headquarters for preplanned missions and from corps or lower army headquarters for immediate missions.

TAC ASSESSOR does not represent air-to-air operations, nor does it model nuclear and chemical deployment, employment, and operations doctrine. Aircraft and field artillery employment and operations limitations prohibit TAC ASSESSOR from meeting the statement of model requirements criteria. TAC ASSESSOR requires the following enhancements:

- Air-to-air operations logic
- Nuclear and chemical deployment, employment, capabilities, and operations logic
- Logic to remove artillery and aircraft limitations
- Precision guided munitions capabilities and operations logic
- Logic to represent national reconnaissance capabilities which can affect corps operations.

3-8.4 VECTOR-2.

The use of artillery or mortar fire in VECTOR-2 is governed by a series of tactical decision rules which specify the type and amount of such fire to be employed in response to either of the following kinds of stimuli:

- The generation of acquired targets by the fire support target acquisition process
- A ground combat situation in which other tactical decision rules specify that the ground commander would request such fire support against a particular target.

When VECTOR-2's representative of the fire support allocation process selects artillery or mortars to engage a particular target (such as an artillery battery, air defense site, or portion of a maneuver unit) an indirect fire module is called upon to compute the effects of the allocated fire. Two types of fire may be represented: area fire and individually targeted fire, and the effects are assessed against the target, dependent upon the type of ordnance being used.

VECTOR-2 models three types of combat involving aircraft: air-to-air combat between penetrating attackers and interceptors; ground-to-air attrition against overflying aircraft; and combat in the target area, including air-to-ground attrition of the target and ground-to-air attrition by air defense weapons in the target area. VECTOR-2 conventional fires include precision guided munitions, air defense artillery, CAS, attack helicopters, and tactical and fixed-wing aircraft. National reconnaissance capabilities which can affect corps operations are represented. Logic to represent nuclear and chemical means, capabilities, and operations doctrine must be incorporated into VECTOR-2.

3-9 COMBAT SERVICE SUPPORT OPERATIONS.

3-9.1 DIVWAG.

The DIVWAG Combat Service Support Model simulates personnel replacement, resupply of critical consumables and expendables, and resupply of major end items, but does not simulate resupply of repair parts. The resupply or replacement process is treated in three essential areas: ordering, distributing, and receiving supplies. DIVWAG essentially represents situation dependent consumption and resulting status for Classes I, III, and V and Class VII losses and status. Transport capabilities and associated times are modeled and distribution priorities are situation dependent.

Support unit locations and road networks are not explicitly represented and stockage levels and support dependent on CSS processing and transport capabilities are not modeled. CSS entities and activities are not subject to attrition and nuclear resupply operations are not represented. The following enhancements should be interfaced with the DIVWAG system:

- CSS entity and transportation network locations and geometry

- Supply stockages at all levels within the division (corps)

- Attrition and damage to CSS entities and activities

- Nuclear warhead resupply.

3-9.2 ICOR.

The explicit representation of CSS is limited to the supply of conventional ammunition and nuclear warhead resupply. ICOR needs logic for representation of CSS status, requirements, and priorities; support unit locations; supply stockages; CSS entity and transportation network locations and geometry; and attrition and damage to CSS entities and activities. The design and development of a CSS operations model should be interfaced with ICOR.

3-9.3 TAC ASSESSOR.

No explicit representation of supplies is made in TAC ASSESSOR. The supply/resupply factor was introduced in an attempt to make a unit which has been cut off from its base of supply less and less effective over time. The supply umbilical of any unit is defined to be the direct path connecting that unit to the headquarters of its immediate superior, then connecting that headquarters to that of its immediate superior, and so on until some headquarters is finally reached which possesses no superior. No alternate supply routes are available, and a unit immediately achieves full effectiveness when its supply links are restored. A supply link is "cut" if any part of it lies within the combat circle of some enemy unit. The design and development of a CSS operations model with nuclear warhead resupply should be developed and interfaced with TAC ASSESSOR.

3-9.4 VECTOR-2.

The VECTOR-2 logistics model represents the arrival to and distribution throughout the battlefield of 76 different types of resources, including personnel, 14 different classes of target acquisition resources, 27 different weapon types and 34 supply types. The weapon types are the following:

- Maneuver unit weapons other than attack helicopters and organic air defense weapons (eight types)
- Field artillery and mortars (five types)
- Air defense artillery (six types)
- Attack helicopters (one type)
- Fixed-wing aircraft (seven types).

The types of consumable supplies represented are the following:

- Ordnance for maneuver unit weapons other than attack helicopters and organic air defense weapons
- Field artillery and mortar ammunition, by weapon type
- Up to 11 types of ordnance for fixed-wing aircraft and attack helicopters (configured into up to ten ordnance load types)
- Land mines
- Ground petroleum, oil, and lubricants (POL)

- Aviation POL

- A general class of other supplies.

Inventories of a given type of resource are maintained at the sector level and within any resource groups (e.g., supply depots, artillery batteries, maneuver units) which the user specifies to contain resources of that type. The user is responsible for developing the tactical decision rules which perform the distribution of these resources to appropriate resource groups. VECTOR-2 does not explicitly treat logistical vehicles, routes, or route capacities. The effects of constrained supply levels on combat activities must also be selected by the user, i.e., the user can choose whether to play the effects of supply shortages, or to ignore such constraints and bookkeep supply requirements. Levels of consumable supplies in VECTOR-2 may be depleted either through consumption or attrition.

Explicit representation of support units, road networks, and route capacities should be interfaced with VECTOR-2. Nuclear warhead resupply operations and attrition and damage to CSS entities and activities should be modeled in VECTOR-2. Incorporation of the TFECS supply logic into VECTOR-2 would reduce these weaknesses.

3-10 ENGAGEMENT AND ASSESSMENT.

3-10.1 DIVWAG.

The Ground Combat Model simulates the interaction between the direct fire weapons of opposing maneuver units engaged in ground combat. DIVWAG permits simulation of the interaction and the effects of weapons of cross-reinforced units. The effectiveness of the maneuver unit is largely dependent upon the combinations and coordination of weapons systems within the unit. The distance of separation of weapons systems is limited so that mutual support is possible when weapon density permits. The impact of the environment is represented in all movement in ground combat and in the application of firepower. DIVWAG contains acquisition and engagement logic for all conventional weapon engagements except precision guided munitions.

The interaction of each maneuver unit with an opponent is considered in terms of a maneuver unit's effectiveness and vulnerability. DIVWAG is sensitive to perceived tactical situations with respect to engagement choices and contains nuclear assessment logic given all employment parameters. The Ground Combat Model processes an engagement by examining the interaction between each attacker-defender pair among all surface units in the engagement. The engagement between each pair is represented by modelling five areas: unit geometry, target acquisition, firepower potential, firepower effectiveness, and assessment. The Ground Combat Model relies heavily on the existence of data to describe weapon/ammunition effectiveness against varying target types in a combat situation. The model also requires data to describe the target acquisition capabilities of all employed sensor types other than unaided vision.

For engagement and assessment, precision guided munitions representation needs to be interfaced with the Area Fire (cannons and missiles), Ground Combat, and Air/Ground Models. The addition of tactical nuclear delivery logic to the Area Fire and Air/Ground Models, and ADM employment logic to the Engineer and Air Models of the DIVWAG system would eliminate these voids.

3-10.2 ICOR

Combat attrition is impacted by a number of operation dependent factors, based upon a Lanchester "square law" model, calculated for each weapon type available, and modified by situational factors. Situational factors include unit posture and disposition as defined by the unit's current operations order, current unit strength (losses), terrain cover and concealment, available weapons and their effectiveness against specified targets as a function of range, and the influence of suppressive fires. The detection, identification, and acquisition process are all represented in ICOR and the Operation Reaction System provides tactical unit engagement opportunities.

Extensive data base development (analysis and preprocessing) is required to produce attrition data adequate to the full range of engagement possibilities for both direct and indirect fire weapons except for precision guided munitions and air defense. Lack of documentation on nuclear weapon attrition methodology forestalls evaluation. Logic should be incorporated into ICOR to calculate attrition rates based on weapons system, method of engagement, target, and environmental parameters. Probable enhancement of nuclear attrition and effects logic, particularly in view of the absence of an Engineer/Barrier Model, will also be required.

3-10.3 TAC ASSESSOR.

Combat induced attrition is governed by a system of Lanchester equations, which have been modified somewhat to take into account some features of combat which might occur in a highly violatile situation, as described below. After initialization, the unit strength over time for a unit in close combat is that of a differential equation (which is numerically integrated in time steps by the Euler method) where the summation extends over all units which are in actual combat contact with unit i. The factors are:

- The coefficient of attrition for the fire of a combat unit of type j when directed against a unit of type i, in direct combat
- The strength of unit j
- The total number of units with which unit j is involved in combat
- A time-dependent vulnerability factor associated with unit i which has the property of decreasing unit vulnerability as a function of the elapsed time in place
- A geometrically determined effectiveness factor applied to the fire of unit j, which decreases its effectiveness depending on the angle off its main axis at which the combat is occurring

- A supply/resupply factor which depends on the time since unit j's line of communication was last open

- A fire effectiveness factor applied to the fire of unit j, which depends on any suppression unit j may have experienced from artillery or aircraft fire.

Several weaknesses require logic extensions in TAC ASSESSOR:

- Ground combat is symmetrical

- No identification and acquisition process representations

- Detection process only performed for aerial attacks

- Precision guided munitions are not modeled

- No engagement or assessment logic for nuclear and chemical employment.

3-10.4 VECTOR-2.

The effects of firepower (and other) processes and combat activities between maneuver forces at the FEBA are computed internally, using differential models of combat. These models describe the dynamics of small unit firefights at the FEBA. The models explicitly consider different weapons system types on each side (tanks, antitank systems, mounted infantry, etc.), characteristics of these weapons systems (their firing rates, accuracy of fire, projectile flight times, lethality of projectile), vulnerability of the target by type firing doctrine of the weapons system (single rounds, burst fire, volley), probabilistic acquisition of targets in the firefight, allocation priorities of weapons systems to targets, maneuver capability of the weapons systems, and the effects of terrain line of sight on acquisition and fire capabilities. The model computes the attrition of weapons systems by type and personnel for the opposing units at successive ranges as the units maneuver during the engagement. Based on user-developed tactical decision rules, the force may break off the combat activity, may call for fire support, or both.

The VECTOR-2 model of force engagement explicitly represents the acquisition and selection of targets during an engagement; a target must be acquired and selected before it can be fired upon. Line of sight must exist between the observing weapon and potential target. Given the existence of line of sight, acquisition may occur by either of two target acquisition models: serial or parallel acquisition. Weapons which employ serial acquisition alternately search for and fire at targets, while weapons employing parallel acquisition can search for new targets while engaging one which has already been acquired and shift fire to a higher acquired priority target. Finally, the highest priority target acquired is selected for engagement. Once a target has been selected, VECTOR-2 computes the resulting attrition and ammunition expenditure. The expected time required to kill the target, given its range and behavior, is used to determine attrition, while the average firing rate is used to determine ammunition expenditure.

Fire support target acquisition is the process by which targets on the ground and in the air are acquired for allocation to fire support resources (artillery, mortars, and TACAIR). Target acquisition resources of a given type are positioned by the model at a characteristic distance from the FEBA, and are assumed to be uniformly distributed along this depth within the zone or corridor in which they are deployed. Two general classes of target acquisition are represented: (1) those which do not adjust fire and are assumed to report an acquired target's location (with an associated error) and then resume searching for other targets and (2) those which do adjust fire and attempt to maintain surveillance of an acquired target until the fire has been delivered; however, they do continue detecting and reporting other targets while awaiting that fire. There are basically three different ways these resources get allocated against targets in VECTOR-2:

- Once-a-day preplanning of air missions against acquired targets

- Periodic, "normal" allocation against acquired targets

- Periodic servicing of "special" allocation requests from front-line areas.

VECTOR-2 attrition reflects the internal dynamics of combat activity and relates to specific weapons system parameters and tactics; the firepower score-force ratio concept is not used. Forces are disaggregated to explicitly consider weapons system types, supplies, and personnel that can be attrited. The amount of attrition is governed by these parameters: engagement decision, munition status, detection, acquisition, target priorities, selection, maneuver capabilities, mission and tactical rules, battlefield environment, perceived tactical situation, opposing force status, and time.

VECTOR-2 does not simulate nuclear and chemical engagement and assessment processes and their effects so the representative logic should be incorporated into the model.

3-11 BATTLEFIELD ENVIRONMENT.

3-11.1 DIVWAG.

The overall area to be gamed is divided into square subareas or cells and cells of any integer number of meters on a side can be selected, but all cells must be of the same size and terrain characteristics are assumed to be homogeneous for a given cell. Each terrain cell is described in terms of cover and concealment characteristics and trafficability by providing three indices for each cell; a roughness and vegetation index, a forest type index, and a trafficability index. The elevation of the terrain is described by the height above sea level (in meters) of each point on the elevation grid. The grid spacing is the same in both the x and y direction, is independent of the terrain cell size, and should be selected to provide sufficient elevation resolution without excessive data requirements. Figure 5 contains a summarization of the use of terrain characteristics by the major DIVWAG models.

Model	Terrain Characteristic	Utilization
Intelligence and Control	Elevation	Used to determine line of sight
Ground Combat	Roughness/Vegetation and Forestation	Used to calculate line of sight probability and background reflectance
Area Fire/ TACFIRE	Forestation	Used to establish vulnerability of personnel
Air Ground Engagement	Roughness/Vegetation and Forestation	Used to compute degradation of air defense weapon effectiveness
Engineer	Trafficability	Used to compute degradation of engineer task performance rates
Movement	Roughness/Vegetation Trafficability	Used to establish average speed of units moving on road Used to establish average speed of units moving cross country
Combat Service Support	Roughness/Vegetation	Used to establish average speed of resupply convoys
Airmobile	Elevation	Used to determine line of sight to air defense weapons

FIGURE 5. USE OF TERRAIN DESCRIPTION WITH DIVWAG SYSTEM

The relations of terrain features, forestation, and man-made facilities which affect significantly (hinder or facilitate) force mobility are considered in the Engineer Model in the context of barriers and facilities. In a division level war game with battalions as maneuver units, individual obstacles of a local nature, unless they are an integral part of a larger barrier line/zone, or are in a rough, mountainous terrain, generally have negligible delaying effect on mobility and are of a nuisance value only. Natural and man-made features having appreciable effects on mobility (e.g., mountains, dense forests, unfordable streams, minefields, and bridges) are integrated into barrier lines of significant extent. Any feature which tends to reduce mobility is treated as a barrier, and any feature which tends to enhance mobility is treated as a facility. In general, barriers may be breached by facilities, through engineer tasks, and those barrier segments which are unsuitable for facilities are designated as unbreachable.

The geographical area subdivided into terrain cells is also subdivided into weather zones to reflect weather conditions. The zones should be established so that each zone has distinct weather parameters, since the model assumes consistency of weather parameters within a weather zone. Within each weather zone, weather is described for each hour of game time in terms of the following parameters:

- Temperature (degrees)
- Precipitation (none, light, or heavy)
- Fog (yes or no)
- Cloud cover (percent)
- Wind speeds (knots)
- Wind direction (azimuth in degrees)
- Relative humidity (percent)
- Visibility index (1-9; 1 worst, 9 best).

Weather parameters are used in the Ground Combat, Air/Ground Engagement, Movement, Intelligence and Control, and Engineer Models. The parameters are generally used in representing the impact of weather conditions affecting local visibility or mobility.

Terrain effects, including obstacles up to division level, weather effects, and obstacles that are nuclear-weapon-induced are all represented in the DIVWAG system. Representation of battle-induced obscuration and electromagnetic influences is not present, therefore, logic and/or data to represent the effects of battle-induced obscuration, EMP, and jamming should be incorporated into the DIVWAG system.

3-11.2 ICOR.

Numerous indices have been included in the data structure relating to the characteristics of each hex which implement the categorization schemes for determining the resultant effects of such features as terrain roughness and vegetation, topography, presence of built-up areas and roads, rivers, bridges, and both natural and artificial barriers. These features generally affect the ease of movement and the choice of movement direction, the target acquisition probabilities, and the relative attrition. Day and night are simulated by their effects on movement and visibility.

A hex grid is used to form the cells for aggregation, with the smallest hex employed in current analysis being 3.57km in "diameter". (This hex size is not a software limitation, but was selected as a satisfactory compromise between resolution and cost, e.g., core storage, run time, etc.) Each cell has been characterized in terms of percentage of cell area that is built-up, forested, and mountainous, which influences movement. Other terrain features that influence movement, such as rivers and roads, are represented by assigning trafficability levels to each hex side for the general orientation of barriers or roads to further affect trafficability. Terrain characterization will assist in dictating the amount of attrition units afforded in combat.

Difficulty in ascribing all the important effects of terrain, weather, and other environmental factors, some of which are battle-induced, to a host of indices for each terrain cell should be corrected. All condition effects are determined a priori and stored in massive tables rather than being calculated from base inputs which are more easily determined at initiation. Additional logic to represent important environmental effects in more explicit, visible, and understandable manners should be interfaced with ICOR.

3-11.3 TAC ASSESSOR.

Each terrain feature is modeled as a rectangle with an arbitrary orientation. Terrain features may overlap and will in general affect the speed and visibility of units which are within them. The contents of the Terrain Feature Dataset for each terrain feature are:

- Name
- Type
- Location
- Orientation
- Half-length
- Half-width
- Velocity modification factor for offensive units
- Attrition modification factor for offensive units
- Average local roughness (obstacle height)
- Distance for viewing probability (density).

Day and night operations are represented, but weather, battle-induced obscuration, and nuclear-weapon-induced effects are not modeled in TAC ASSESSOR and should be incorporated in the Terrain Feature Dataset and model algorithms.

3-11.4 VECTOR-2.

The effects of terrain, terrain features, and weather conditions are represented in VECTOR-2. Terrain is classified independently for six levels of terrain intervisibility (line of sight) and six levels of trafficability. Thus, 36 types of terrain can be represented in the model. Terrain is assumed to be homogeneous within a combat arena*, but may vary from arena to arena. In addition, a variety of terrain features are represented in the model, which include urban areas, rivers, and an unidentified terrain feature that can be specified by the user in the model. Each terrain feature occupies its own arena, and is assumed to extend across the entire width and depth of the arena.

Weather conditions in each sector of the battlefield can be input to the model for every hour of the simulated campaign. Weather is represented in terms of four levels of each of the following characteristics:

- Weather visibility for ground-to-ground operations
- Weather visibility for ground-to-air and air-to-ground operations
- Weather visibility for air-to-air operations
- Weather trafficability for ground operations (used to represent the effects of adverse weather conditions such as rain or snow on terrain trafficability)
- Weather trafficability for air operations (used to represent the effects of wind speed and direction on air operations).

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*VECTOR-2 considers the battlefield to be divided into seven sectors and each sector is divided into areas called combat arenas.

Determining the effects of precipitation on the movement of vehicles necessitates knowing the types of terrain over which movement is being conducted. To reflect the combined effect of weather and terrain on ground trafficability, an environmental trafficability index is determined within the model as a function of the current weather trafficability index for ground movement and the terrain trafficability index. Six levels of environmental trafficability are represented. Similarly, an environmental visibility index is computed within the model as a function of the current weather visibility index for ground-to-ground operations and the terrain visibility index. Six levels of environmental visibility are available and are used by the model when the combined effects of terrain line of sight and weather on ground visibility are needed.

VECTOR-2 does not model battle-induced obscuration and its effects, electromagnetic influences, and nuclear-weapon-induced obstacles and their effects. Logic to represent these important battlefield factors and their effects should be incorporated into VECTOR-2.

3-12 POSTPROCESSOR.

3-12.1 DIVWAG.

The Analysis Output Processor is composed of two sets of computer programs: Information Retrieval and Display System (IRADS) and Statistical Tabulations (STATAB).

The function of the IRADS programs is to extract data from the history tapes produced by the Period Processor and to array the data in proper form for the STATAB programs. Additionally, the IRADS programs have the capability of printing a formatted copy of all or selected records from the history tapes.

The purpose of the STATAB program is to perform the numerical operations of the nonparametric statistical analysis of the game output. The STATAB program embraces all statistical problems in a multiple rank ordering process. Game data are organized by functional area, and effectiveness indicators are defined to support the measures of effectiveness that pertain to each functional area. A one-way analysis of variance (ANOVA) is applied to game data arrayed by unit or system type for each effectiveness indicator. This ANOVA utilizes the Kruskal-Wallis one-way ANOVA and the Mann-Whitney U-Test (one-way) to acquire rank ordering of performance by unit type and system type. After acquiring unit/system ranks for each effectiveness indicator, effectiveness indicators applicable to each function of level combat are assembled into sets, and their attendant ranks within sets are gathered into an array, which is subject to the Friedman two-way and the Mann-Whitney two-way test. The sequential application of one-way ANOVA for all indicators followed by a two-way ANOVA results in a final rank ordering of units and systems for each functional area of combat.

The IRADS and STATAB provide a comprehensive capability on which a thorough analysis of game results can be made. The Period Output Processor which produces a set of postperiod reports upon completion of the game period to be used as guidance in preparing orders for the following period provide game support. DIVWAG's postprocessor contains no major shortcomings, but it is minimal to the particular needs of the doctrinal evaluation.

3-12.2 ICOR.

ICOR outputs produced during a run are "state snapshots" presenting the status of some or all of the simulated force elements at a particular point in time. "Physical status" snapshots represent the true state of all force elements at a given point in time. Physical status output data include the position, status, strengths, and losses of each unit. Air results listings provide information on aircraft status by type, results of sorties flown, targets attacked with munitions that have residual effects, and losses from air defense weapons. Direct fire kills against each enemy asset type are displayed and a sensor status listing reveals the activity, location, and number of sensors remaining under each commander's control. The intelligence report consists of listings on nonemitting targets by location and emitting targets by time. Artillery and munitions statistics present number of missions by type that were executed, kills by mission, kills at various ranges, and kills by munition type. The mass/momentum (ground truth) listing displays tanks and vehicle movements as a "force vector" by multiplying the number of vehicles moving in a given direction by their speed to obtain a momentum value.

Other ICOR outputs include the perception outputs containing the line of contact report which displays the line of contact of both forces and the intensity of battle in which the units are engaged. The perceptions of mass/momentum listing provides force vectors based on the speed, direction, and number of vehicles from available intelligence assets. The graphics output from the ICOR model is obtained by running a program called "Grafix" interactively with a Textronix 4014 terminal.

ICOR's postprocessor contains no special analytic procedures extant to support analysis. Logic to support the analysis and evaluation plan must be incorporated into ICOR's postprocessor.

3-12.3 TAC ASSESSOR.

Outputs generated by TAC ASSESSOR can include event data, batch plots, and interactive graphics. The Programmer's Notebook defines the contents of each type of dataset and includes all the 173 dataset types, both those that must be input by the user and those calculated by the simulation. The TAC ASSESSOR model has an elaborate interactive graphics display package whereby the user can display maps of the true battlefield situation, maps of any headquarter's perception, communication nets, all datasets in the data base, production rules, and/or signature tables. One also can save the state of the data base, restart the simulation at an earlier time, bypass the display processing until a particular time or condition is reached, or terminate the simulation. The display package can show several different maps of the battlefield situation: either the true situation as it exists at that time or the situation as any ground command headquarters perceives it. The "true situation" map, in addition to displaying the true position of friendly and enemy units, can display terrain features, sensor capabilities of the units, velocity vectors, and path histories. The "perception" map can optionally display perceived battle lines, FLOT (forward line of own troops), FLET (forward line of enemy troops), and objective locations, control boundaries between subordinate units, planned path points for units, path histories, and areas of current intelligence, as well as the perceived locations of friendly and enemy units. The batch plot module produces line printer plots of the true battlefield situation and perception maps of designated commanders.

TAC ASSESSOR does not perform measure of effectiveness and statistical calculations. Software to perform these calculations should be interfaced with TAC ASSESSOR so that the necessary information can be captured for the analysis and evaluation of doctrinal alternatives.

3-12.4 VECTOR-2.

The total history of all important state variables during a campaign is stored by the model for use by the VECTOR-2 postprocessor. Representative model outputs which the postprocessor can produce include:

- Model time period and cumulative weapons system losses by weapon type
- Model time period and cumulative casualties
- Supply totals by type of supply
- Total weapons system survivors by weapon type
- Weather conditions
- A map of the battlefield including zone
- Acquired targets by type
- Numbers of sorties flown on each mission by each aircraft type

- For each front-line task force:
  - number of weapons systems (by type), number of personnel, and supply levels
  - minefields deployed
  - FEBA position
  - distance the force moved during the current time period
  - current activity
  - reserve units employed

- Attributions of casualties (by location) and weapons system losses (by type) to
  - maneuver unit weapons (and air defense artillery in the case of helicopter kills)
  - fixed-wing aircraft (and air defense artillery in the case of aircraft losses)
  - field artillery
  - attack helicopters.

VECTOR-2 does calculate various measures of effectiveness (as listed above) and all state and output variable data are saved. No summary statistics are calculated so logic for those desired calculations to support the analysis and evaluation of doctrinal alternatives must be interfaced with VECTOR-2.

SECTION IV
SUMMARY OF MODEL REVIEW AND RESULTANT RECOMMENDATION

4-1 GENERAL.

This section summarizes the model/war game assessment, recommends a model, and presents rationale as to why that model was selected to assist in evaluating the tactical nuclear doctrinal alternatives for the integrated battlefield.

4-2 SUMMARY OF MODEL/WAR GAME RESULTS.

Table 1 presents the overall summary of results of the model/war game review. For each area of consideration, each model was given a grade based on the degree of enhancement necessary to meet the statement of model/war game requirements criteria. The model received an "A" if the area of consideration was fully adequate and no enhancements were necessary. If the model required a few modest enhancements or if executing that area of consideration required a substantial user effort to implement, the model received a "B". The third and only other grade that could be awarded was "C" which indicated that several and/or substantial enhancements were required to upgrade the model to that level specified by the statement of model/war game requirements criteria. The following paragraphs explain model area of consideration grade assignments.

TABLE 1

OVERALL SUMMARY OF RESULTS OF MODEL/WAR GAME REVIEW

Area of Concern → / Model ↓	Preprocessor and Data Base Management	Operations Planning	Command Control and Communications	CSS Planning	Intelligence & Fusion	Tactical Maneuver of Forces	Combat Support Operations	CSS Operations	Engagement & Assessment	Battlefield Environment	Postprocessor
DIVWAG	C	B	B	A	B	C	C	B	B	B	A
ICOR	B	B	C	C	B	B	C	C	B	B	B
TAC ASSESSOR	B	B	B	C	B	B	C	C	C	C	C
VECTOR-2	B	B	B	B	B	B	B	B	B	B	B

A = Fully Adequate

B = Modest Enhancement Needed and/or Substantial Implementation Efforts Required

C = Substantial Enhancement Needed

4-2.1 Preprocessor and Data Base Management.

DIVWAG is a division level model that only has a batch processing capability and requires laborous data base verification. Extensive enhancements are required of the resolution/nonresolution unit feature to develop a corps level model and DIVWAG should be enhanced to permit interactive use at any organizational level. Based on these substantial enhancement requirements, DIVWAG was assigned a "C" in this area of consideration.

ICOR requires extensive analysis and preprocessing to validate input parameters. Enhancement is required for interactive use of ICOR at organizational levels above brigade. No improvements are needed for batch operation at the corps level given extensive input preparation between periods. Given the modest enhancement needed and the substantial input and data base preparation and validation, ICOR was assigned a "B".

TAC ASSESSOR is a heavily data-dependent model requiring much time and care in preparing, modifying, and verifying the input data and data base. Locating data errors is extremely difficult due to the amount and complexity of data and that the model software only checks for syntax. Given these substantial input requirement efforts, TAC ASSESSOR was given a "B".

VECTOR-2 requires data to describe the quantitative performance capabilities of the forces, weapons systems, and other resources; initial force and supply inventory data; data describing the environment (terrain and weather); the tactical decision rules; and initial intelligence information. The tactical decision rules (data input) drive the results of many of the areas of consideration and require careful and lengthy preparation and verification. VECTOR-2 was assigned a "B" due to the substantial effort required to prepare the tactical decision rules.

4-2.2 Operations Planning.

DIVWAG does not represent tactical nuclear planning, i.e., all nuclear planning activities are manual and must occur between simulated periods. TACAIR is not fully representative of the system in that no methodology exists for army group TACAIR and corps level activities. For these modest enhancements, DIVWAG was given a "B".

All decision-making and essential planning above the battalion level require massive man-in-the-loop efforts. Lower level planning activities are not in the ICOR software. ICOR was awarded a "B" for this area of consideration.

TACAIR planning is not fully representative of the NATO system and TAC ASSESSOR contains no logic for nuclear and chemical operations planning thus TAC ASSESSOR was given a "B".

Nuclear and chemical deployment procedures can be implemented by altering the tactical decision rule logic in VECTOR-2 to reflect the use of nuclear and chemical weapons. A lot of time and care must be given to the development, structuring, and inputting of the tactical decision rules so that user desired plans and contingencies are properly represented, therefore, VECTOR-2 was awarded a "B" for operations planning.

4-2.3 Command Control and Communications.

DIVWAG does not represent message volume, capacity, and queuing and command element vulnerabilities to intercept, jamming, and EMP. Representation of attack by fire is inadequate for analysis purposes. DIVWAG was given a "B" for these modest enhancements.

All C^2 functions and decision-making above battalion level in ICOR are primarily simulated by man-in-the-loop. ICOR contains no explicit representation of communications except for sensor operations, situation reporting, and operation delay times. A communications submodel is required with representation of operations procedures/profiles and vulnerabilities. ICOR should contain a C^2 submodel for selected division and brigade level situation assessment, decision-making, and orders issuance activities. ICOR received a "C" for these substantial enhancements.

TAC ASSESSOR does not represent skip echelon and echelon bypass capabilities and EMP effects therefore a "B" was assigned to TAC ASSESSOR for the C^3 area of consideration.

VECTOR-2 does not represent EMP effects and communication degradation. Only a vertical command element hierarchy exists whereby a unit receives its commands from and provides feedback to one and only one commanding unit. These modest enhancements that should be made permit VECTOR-2 to be assigned a "B".

4-2.4 Combat Service Support Planning.

DIVWAG CSS modelling deficiences are due to those factors and processes not represented in DIVWAG's CSS operations (see 4-2.8). No enhancements are required in CSS planning; DIVWAG was awarded an "A".

CSS planning is not represented in ICOR. A CSS planning submodel is needed containing the processes and essential representations outlined in the statement of model requirements. This substantial enhancement to ICOR necessitated that the model be given a "C" in this area of consideration.

Similar to ICOR, CSS planning is not represented in TAC ASSESSOR and logic for the processes and essential representations should be interfaced into TAC ASSESSOR. A "C" was assigned to TAC ASSESSOR due to this substantial enhancement requirement.

The VECTOR-2 tactical decision rules govern all resource allocations and distributions to appropriate groups and the effects of constrained supply levels on combat activity. The efforts required to develop the tactical decision rules for CSS planning necessitated giving VECTOR-2 a "B" in this area of consideration.

4-2.5 Intelligence and Fusion.

Not all sensors needed are currently represented in DIVWAG and the effects of EMP, deception, and jamming are not modeled. DIVWAG was assigned a "B" for these modest enhancements.

The man-in-the-loop tasks each sensor system individually, identifying mission time and duration, flight path, radar or camera orientation, and "swath range" (if a system variable). Even though sensor performance is modeled in ICOR, all sensor tasking (collection management) occurs either at initialization or by man-in-the-loop and all CEWI and TOC operations occur between periods via man-in-the-loop assessment of sensor/intelligence reports. ICOR should simulate realistic and timely representation of the CEWI Operations Center, the TOC, and vulnerabilities to EMP and deception. For these enhancement requirements, ICOR was assigned a "B" in this area of consideration.

The communications module in TAC ASSESSOR simulates the effects of facility-loading, jamming, garbling, and relaying, however, EMP effects and deception are not represented. TOC activities are limited to the corps level and CEWI operations are not modeled. TAC ASSESSOR was awarded a "B" for these modest enhancement requirements.

The tactical decision rules manage intelligence at all levels in VECTOR-2. The service characteristics of the communications system are not subject to change by attrition or EW (which is not represented in VECTOR-2). A "B" was assigned to VECTOR-2 due to these modest enhancement requirements and the tactical decision rule effort.

4-2.6 Tactical Maneuver of Forces.

Tactical and administrative movement of units by ground or air in the movement model is in response to gamer-planned DSL orders. The gamer must plan, coordinate, and schedule all movement performed by DIVWAG at game initialization (DIVWAG is not interactive). Unit mission choices are entirely DSL order dependent so logic to represent unit mission and activity dependencies on unit operational status needs to be added to the DIVWAG system. C^2 capabilities and vulnerabilities representation embodies only the effects of time delays, therefore, logic to represent the reduced effectiveness or loss of C^2 capabilities on the tactical maneuver of forces should be incorporated into the DIVWAG system. These major enhancement requirements necessitated assigning DIVWAG a "C" for this area of consideration.

Logic to represent the effects of CSS status on combat capabilities and the reduced effectiveness or loss of C^2 capabilities should be added to the ICOR model. ICOR was given a "B" for these modest enhancement requirements for the tactical maneuver of forces.

Logic to represent the effects of C^2 capabilities and vulnerabilities, CSS status, and exposure profiles should be incorporated into TAC ASSESSOR to properly represent the tactical maneuver of forces. These modest enhancements permit TAC ASSESSOR to be given a "B" in this area of consideration.

VECTOR-2 tactical decision rules identify task organizations, specify major controls, allocate combat support, and define effects of unit CSS status. Efforts required to develop, input, and interactively redefine (as appropriate) the tactical decision rules necessitated assigning VECTOR-2 a "B" for the tactical maneuver of forces.

4-2.7 Combat Support Operations.

DIVWAG models employment doctrine, rules, and constraints for conventional combat support, but not for chemical operations and precision guided munitions. No aspects of nuclear employment doctrine are represented and reconnaissance operations at the national level are not modeled. Due to the substantial enhancements needed, DIVWAG was assigned a "C" for combat support operations.

Chemical warfare capabilities and doctrine, combat engineering capabilities and doctrine, and reconnaissance operations at the national level are not represented in ICOR. Nuclear employment representation except for nuclear warhead resupply must be performed manually by man-in-the-loop. ICOR was also given a "C" for this area of consideration due to the number and magnitude of the enhancement requirements.

TAC ASSESSOR does not consider different effects for different artillery round types employed by the same unit and similarly the model assumes all aircraft in a flight are the same type, have the same ordnance, and all fire at the same target. TAC ASSESSOR does not represent air-to-air operations, nor does it model nuclear and chemical deployment, employment, and operations doctrine. Aircraft and field artillery employment operations limitations prohibit TAC ASSESSOR from meeting the statement of model/war game requirements criteria in these areas. Precision guided munitions capabilities which can effect corps operations are not modeled. TAC ASSESSOR was assigned a "C" due to these voids in combat support operations representation.

The use of artillery or mortar fire in VECTOR-2 is governed by a series of tactical decision rules as described in 3-8.4. Logic to represent nuclear and chemical means, capabilities, and operations doctrine must be incorporated into VECTOR-2. A "B" was given to VECTOR-2 for the enhancement and development of the tactical decision rules.

4-2.8 Combat Service Support Operations.

Support unit locations and road networks are not explicitly represented and stockage levels and support dependent on CSS processing and transport capabilities are not modeled in DIVWAG. CSS entities and activities are not subject to attrition and nuclear resupply operations are not represented. DIVWAG was assigned a "B" for this area of consideration.

The explicit representation of CSS operations in ICOR is limited to the supply of conventional ammunition and nuclear warhead resupply. ICOR needs logic for representation of CSS status, requirements and priorities, support unit locations, supply stockages, CSS entity and transportation network locations and geometry, and attrition and damage to CSS entities and activities. Since ICOR essentially needs a CSS operations model incorporated into the system, the model was given a "C".

Explicit representation of CSS operations does not exist in TAC ASSESSOR. A supply/resupply factor was introduced in an attempt to make a unit which has been cut off from its base of supply less and less effective over time. Since the design and development of a CSS operations model with nuclear warhead resupply should be interfaced into TAC ASSESSOR, the model was assigned a "C".

The user is responsible for developing the tactical decision rules which determine the distribution of assets, the effects of constrained supply levels on combat activity, and the depletion of supply through consumption or attrition. Explicit representation of support units, road networks, route capacities, nuclear resupply operations, and attrition to CSS entities and activities should be incorporated into VECTOR-2. Since combat service support operations are at least implicitly represented through the use of the tactical decision rules, VECTOR-2 was assigned a "B" for this area of consideration.

4-2.9 Engagement and Assessment.

Precision guided munition, tactical nuclear delivery, and ADM employment logic needs to be incorporated into the DIVWAG system models. For these modest enhancements, DIVWAG was given a "B" for the engagement and assessment area of consideration.

Extensive data base development (analysis and preprocessing) is required to produce attrition data adequate to the full range of engagement possibilities for both direct and indirect fire weapons except for precision guided munitions and air defense. Lack of documentation for nuclear weapon attrition methodology forestalls evaluation. Logic should be incorporated into ICOR to calculate attrition rates based on engagement parameters. ICOR was assigned a "B" due to these needed enhancements.

Several weaknesses require that logic be incorporated into TAC ASSESSOR: ground combat is symmetrical, no identification and acquisition processes, detection only for aerial attacks, precision guided munitions are not modeled, and no engagement or assessment logic for nuclear and chemical employment. These deficiencies necessitated giving TAC ASSESSOR a "C" for engagement and assessment.

VECTOR-2 does not simulate nuclear and chemical engagement and assessment processes and their effects so VECTOR-2 was assigned a "B" for this deficiency.

4-2.10 Battlefield Environment.

Representation of battle-induced obscuration and electromagnetic influences is not present in the DIVWAG system so a "B" was assigned to DIVWAG for the battlefield environment area of consideration.

Difficulty in ascribing all the important effects of terrain, weather, and other environmental factors, some of which are battle-induced, to a host of indices for each terrain cell should be corrected in ICOR. More explicit representation of the battlefield environment should be incorporated into ICOR, but due to the model's present state of difficulty in preparing the parameters, ICOR was given a "B".

Weather, battle-induced obscuration, and nuclear-weapon-induced effects are not modeled in TAC ASSESSOR. Major modifications to the model in this area of consideration require that TAC ASSESSOR be assigned a "C".

VECTOR-2 does not model battle-induced obscuration and its effects, electromagnetic influences, and nuclear-weapon-induced obstacles and their effects. A "B" was given to VECTOR-2 for these modest enhancements.

4-2.11 Postprocessor.

DIVWAG's Analysis Output Processor is composed of two sets of programs: Information Retrieval and Display System (IRADS) and Statistical Tabulations (STATAB). IRADS programs extract data from the history tapes produced by the Period Processor and array the data in proper form for the STATAB program. IRADS programs also print a formatted copy of all or selected records from the history tapes. The STATAB program performs the numerical operations of the nonparametric statistical analysis of the game output. DIVWAG's postprocessor contains no major shortcomings so it was awarded an "A" for this area of consideration.

ICOR's postprocessor, unlike DIVWAG's, contains no special analytic procedures extant to support analysis. Since logic is required to support the analysis and evaluation plan, ICOR was assigned a "B".

Outputs generated by TAC ASSESSOR can include event data, batch plots, and interactive graphics. TAC ASSESSOR does not perform measure of effectiveness and statistical calculations; the written reports only consists of event data so a "C" was given to this model for the needed enhancements.

VECTOR-2 calculates various measures of effectiveness and all state and output variable data is saved. No battle summary calculations are performed so VECTOR-2 was assigned a "B" for this modest enhancement.

4-3 RECOMMENDATION WITH RATIONALE.

Overall ratings for each model reviewed were determined and the models were ranked accordingly:

1. VECTOR-2
2. DIVWAG
3. ICOR
4. TAC ASSESSOR

Based on these results of the model/war game assessment, VECTOR-2 is the model recommended. Enhancement efforts will be minimized by incorporating the TFECS logic (which has been developed and is ready for interface) for many of the areas of consideration into VECTOR-2 (as specified in Section III). Given these interfaces, VECTOR-2 needs only to be upgraded from a conventional warfare model to one that plays the integrated battlefield.

Noteworthy is the extensive use of VECTOR-1 in a 1976 study of tactical nuclear force versatility planning, performed for the Defense Nuclear Agency. Although the VECTOR-1 model (and similarly VECTOR-2) does not inherently provide logic for the representation of nuclear warfare, its flexibility allowed the inclusion of such logic through the tactical decision rules input by the user. With such a device, the UNICORN nuclear weapons allocation and damage assessment model essentially became a subroutine of VECTOR-1. Such flexibility is also present in the VECTOR-2 model. Therefore, subroutines can be added to the VECTOR-2 system, with relative ease compared to other models, to simulate nuclear and chemical warfare. This rationale contributed to recommending that VECTOR-2 be the model used in the evaluation of doctrinal alternatives for the integrated battlefield.

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APPENDIX A

ABBREVIATIONS AND ACRONYMS

ADM	atomic demolition munition
ANOVA	analysis of variance
BDE	brigade
BN	battalion
CAS	close air support
C^2	command control
C^3	command control and communications
C^2I	command control and intelligence
C^3I	command control, communications, and intelligence
CEWI	combat electronic warfare and intelligence
CSS	combat service support
CSWS	corps support weapon system
DIV	division
DNA	Defense Nuclear Agency
DSL	DIVWAG source language
ECM	electronic countermeasure
EEA	essential elements of analysis
EEI	essential elements of information
EMP	electromagnetic pulse
ENSIT	enemy situation

EW	electronic warfare
FEBA	forward edge of the battle area
FLET	forward line of enemy troops
FLOT	forward line of own troops
FRENSIT	friendly situation
HUMINT	human intelligence
I-P-O	input-process-output
IRADS	Information Retrieval and Display System
MOE	measures of effectiveness
NATO	North Atlantic Treaty Organization
OIR	other intelligence requirements
OPSEC	operations security
POL	petroleum, oil, and lubricants
RGT	regiment
STATAB	Statistical Tabulations
TACAIR	tactical air
TFECS	Theater Force Evaluation by Combat Simulation
TOC	Tactical Operations Center
UGS	unattended ground sensor

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