Proceedings of the 2008 Winter Simulation Conference
S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler eds.

CREATING AND USING NON-KINETIC EFFECTS: TRAINING JOINT FORCES FOR ASYMMETRIC OPERATIONS

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ABSTRACT

US military forces now face asymmetric military operations. Management of relationships with civilians is often crucial to success. Local population groups can provide critical intelligence or be sources of increasingly violent insurgent activity. A variety of organizations that are neither citizens nor military forces complicate the scenario. Mission readiness and rehearsal training are evolving to respond to this new operating environment. In particular, the Joint Land Component Constructive Training Capability (JLCCTC) adds the Joint Non-kinetic Effects Model (JNEM) and the Independent Stimulation Module (ISM) to any of several combat models. JNEM models the non-kinetic effects of joint military operations on the attitudes and reactions of civilian population groups. ISM manages the flow and delivery of information. All components of JLCCTC communicate in real time during training. Commanders learn that appropriate actions improve the situation (e.g., better cooperation) and inappropriate actions make things worse (e.g., increased numbers of insurgents).

1 INTRODUCTION

Traditionally, US military training systems were oriented toward Cold War scenarios. They focused on large force-on-force operations facing an enemy with similar capabilities. However, in recent years the focus has changed to counterinsurgency and asymmetric warfare. It became necessary for the training systems to change focus too. This paper describes the architecture, implementation, and operational context of a military readiness training system for counterinsurgency operations.

Section 2 outlines the operational and technical environment. Section 3 describes the internal construction of the Joint Non-kinetic Effects Model (JNEM), including the consensus-based design approach. Section 4 describes the role of the Independent Stimulation Module (ISM). The paper concludes with some ideas for future development.

2 ENVIRONMENT

2.1 Operational Environment

Before deploying to a theatre of war, US Army commanders and their staffs undergo a mission readiness exercise. This exercise is a dress rehearsal, where simulated events and actions are presented to the commanders, analyzed by their staffs, and acted on by subordinate commanders. The simulated events represent the challenges the commanders can expect to face when deployed. Mission readiness exercises typically last five days with twenty-four-hour-per-day operations.

In this context, the commanders and staffs are known as the *training audience.* During an exercise, the training audience works from tactical operations centers, often tents or trucks, while executing the planning and decision process. Orders are sent to subordinate units, and reports from subordinates are received by command and control systems (C2), which may include formatted text, voice, email, or chat.

The lower-echelon army units, as well as enemies and neutrals, are simulated in a federation of computer models. Inputs and outputs to the models occur through the C2 systems and through human intermediaries known as *role players*. The training audience does not directly interact with the simulation. The role players act as subordinate commanders, entering orders into a federation of simulation models and reporting on results from the simulated battlespace using standard military procedures. They also control the simulated enemy and neutral civilian elements. Role players are typically senior or retired military officers with specific expertise and experience in their functional area. A cadre of retired general officers and

978-1-4244-2708-6/08/$25.00 ©2008 IEEE

diplomats observe the exercise and critique and mentor the active-duty commanders' performance.

Other key roles for humans are the Exercise Director, charged with ensuring that training objectives are met, and Technical Controllers, who operate the computer hardware and software.

2.2 Modeling Environment

A key DoD tool for this type of training is the Joint Land Component Constructive Training Capability (JLCCTC). JLCCTC is an interactive, multi-sided wargaming system designed to support mission readiness and rehearsal at tactical and operational levels of warfare. In various configurations, it supports training of corps-, division-, brigade-, and battalion-level staffs. The system is a High Level Architecture (HLA) federation. HLA is a general-purpose architecture for distributed simulation systems. In an HLA federation, each component communicates through a Run Time Infrastructure (RTI). The RTI is essentially a network operating system using the HLA protocol.

The federation is centered on one of several combat models, all of which were originally designed to model high-intensity conflict in cold-war scenarios, where victory would be achieved by attrition of enemy forces, destruction of infrastructure, and occupation of territory. The combat model is integrated, or federated, with several supporting models, all of which exchange object state and event data as simulated time progresses. These include JNEM, described in detail in the following section, and the Independent Stimulation Module (ISM), described in Section 4, which provides the interface between the simulation federation and the training audience via C2 systems.

3 THE JOINT NON-KINETIC EFFECTS MODEL

3.1 Development Process

3.1.1 JNEM Modeling and Rules Committee

All of the key people who have a vested interest in the quality of the JNEM model—senior observers, exercise designers, opposition force role players, modelers, programmers, and occasionally past members of the training audience who have returned from their deployment—get together two or three times during the annual development cycle to ensure that the models and rules are relevant to the users' needs.

At the first of these meetings, which usually occurs late in the previous development cycle, the focus is on developing an understanding of new user requirements. This meeting concentrates on determining and prioritizing what the training audience wants to be able to do that is not yet supported. Model concepts are developed for and presented at the next meeting, which focuses on whether those model concepts address the perceived needs. There is usually a third meeting to ensure that subsequent detailed designs still meet the users' requirements, which sometimes change in response to world-wide current events.

In this context, the customer is quite sophisticated and has a great deal of expertise in the subject matter of the models. Smaller meetings are held between modelers and user-supplied subject matter experts in the course of developing model concepts. These SME meetings usually also produce default values for parameters and other data, which are subsequently ratified (or modified) by the full committee.

3.1.2 Exercise Design and Data Preparation

After training objectives are set by the exercise director, a large volume of data must be assembled and formatted for consumption by the computer models. This data includes descriptions of the physical environment, the armed forces involved (order of battle data), and parametric data on the performance of all simulated systems.

In the case of JNEM, this data includes geographic boundaries of neighborhoods and the populations and some demographic characteristics of the various civilian groups residing therein. This might be considered *census data* in a domestic context. Also required are definitions of the relationships between each pair of population groups in each neighborhood.

All data are stored as ASCII text, which can be modified at the exercise site without the need to change computer code.

3.2 JNEM Overview

All the people in the playbox (that is, in the geographic region in which the simulation takes place) are assumed in the simulation to be in one of three kinds of population groups: *civilian*, *force*, or *organization*. The people who live in the neighborhoods are collected into *civilian* population groups by shared ethnicity, religion, language, social class, or other demographic criteria as appropriate to the playbox and to the purpose of the simulation. Military, paramilitary, militia, police, and criminal elements are categorized as *force* groups. Intergovernmental, non-governmental, and contractor *organization* groups may also be operating in the neighborhoods.

JNEM consists of three logical parts. First, it uses a set of input rules to watch what is going on in the combat simulation. Those rules determine how civilian satisfaction levels change. Satisfaction is tracked for several concerns. Cooperation levels are also tracked. Based on the forces available to each neighborhood group and the vola-

tility of the neighborhood, JNEM also estimates how secure each group is in each neighborhood.

Next, it uses inter-group relationships to determine how changes in satisfaction and cooperation propagate to friends and enemies, both locally and in other neighborhoods.

Finally, it considers neighborhood groups' *moods* (computed as saliency-weighted combinations of satisfaction levels) and demeanors to control the number of insurgents they support and to assign civilian activities and hostile actions.

Satisfaction levels are also tracked for non-governmental organizations, inter-governmental organizations, and contractors. Their concerns are, of course, different from those of the citizens.

Organizations are concerned—some more than others—about the number of casualties they have taken. If the numbers are too high, they work at reduced effectiveness in some neighborhoods and stay out of others altogether.

3.2.1 Concerns

Satisfaction, expressed as a number between –100 and +100, is a measure of the strength of motivating factors, including perceived relative deprivation (Gurr 1970).

Technically, the population groups' concerns are part of the JNEM database, not part of its structure. That is, the sets of concerns can be expanded and changed. Application to a different region, with different kinds of people, may require such changes. Practically speaking, however, it must be noted that the input and output rules are intimately related to the concerns that have been identified and defined. Thus, the list has seen changes between successive versions of JNEM, but short-fuse changes by users are not really feasible.

Civilian concerns in JNEM Version 3 are:

- **Autonomy (AUT):** Does the group feel it can maintain order and govern itself with a stable government and a viable economy?
- **Safety (SFT):** Do members of the group fear for their lives, either from hostile attack or from collateral damage from force activities? This fear includes environmental concerns such as life-threatening disease, starvation, and dying of thirst.
- **Culture (CUL):** Does the group feel that its culture and religion, including cultural and religious sites and artifacts, are respected by others?
- **Quality of Life (QOL):** QOL is affected by the condition of the physical plants that provide services, including water, power, public transportation, commercial markets, hospitals, etc. and those things associated with these services such as sanitation, health, education, employment, food, clothing, and shelter.

Organizations have the following concerns:

- **Casualties (CAS):** How dangerous the group views its environment to be in relationship to its members' willingness to risk (or continue risking) their lives to do their work. If their satisfaction with the number of casualties is too low, members of the group may refuse to work.
- **Service (SVC):** The group's satisfaction with the service it is providing to the civilians. Organization groups have higher SVC satisfaction when performing their work and lower satisfaction when inactive.

Concerns are not equally important. Relative and absolute importance varies between population groups and even from neighborhood to neighborhood within a population group. Importance is measured in JNEM by a parameter called *saliency*.

3.2.2 Inter-group Relationships

A *relationship matrix* expresses how much each group is affected by satisfaction changes in each other group. Values range from –1.0 to +1.0. If group A's relationship with group B has a value of +1.0, then group A feels group B's changes just as if the events that caused the changes had happened to it; thus, the diagonal of the matrix contains +1.0 values. A negative value means that group A's satisfaction increases when B's decreases. A value of –1.0 would be truly pathological, as the intensity of the pleasure experienced by members of group A when something bad happens to people in group B would be just as high (though with the opposite sign) as the intensity of the pain experienced by the members of group B. Typical data values for groups that hate each other enough to enter into civil war might be –0.6.

Relationships are not expected to change during typical mission readiness exercises, but changes will have to be modeled when longer time horizons are considered.

3.2.3 Cooperation

The cooperation model in JNEM is a partial implementation of the HUMINT methodology developed by TRADOC TRAC (the TRADOC Analysis Center of the Training and Doctrine Command at Fort Leavenworth, Kansas).

Cooperation between two groups is expressed as a number from 0 to 100, and is interpreted as the probability that the first group will give information (intel) to the second. The matrix is highly unlikely to be symmetric. As with many variables in JNEM, numerical values can also be expressed in narrative terms, as in Table 1.

The TRAC methodology allows for computation of cooperation between any pairs of groups; JNEM tracks cooperation matrices for every neighborhood, but only between civilians and forces.

Initial cooperation levels are part of the exercise design. Changes result from force activities.

Table 1: Cooperation values. Values can be expressed as a range of values by a narrative string or by a symbol. When crisp values are needed for computation, any values that were input as ranges are replaced by a nominal value. Computations are always numerically crisp (never "fuzzy"). On output, crisply computed values are expressed in terms of the ranges in which they fall.

Cooperation Narrative, Symbolic Value	Range of Values	Nominal Value
Always Cooperative, AC	99.9–100	100.0
Very Cooperative, VC	80.0–99.9	90.0
Cooperative, C	60.0–80.0	70.0
Marginally Cooperative, MC	40.0–59.9	50.0
Uncooperative, U	20.0–39.9	30.0
Very Uncooperative, VU	1.0–19.9	10.0
Never Cooperative, NC	0–1.0	0.0

Rule definitions specify a nominal rate of change for cooperation for each kind of force activity. (Activities are listed in Section 3.3.) They also specify a relationship multiplier function that takes the relationship between the two groups as its argument and produces a multiplier appropriate for each kind of activity.

Effectiveness depends on neighborhood force density and on which activity is being performed, but application of additional resources shows diminishing marginal utility. So, JNEM computes a coverage fraction that approaches the value +1.0 asymptotically with increasing force density.

Nominal cooperation change rates are computed as the product of these three numbers. To ensure that cooperation numbers stay within the bounds of 0 to 100, nominal changes are considered to be percentage changes of the difference between the current value and 100 or 0, depending on whether nominal changes are positive or negative.

3.2.4 Neighborhoods

Relationship matrices are used to estimate indirect effects within each neighborhood and between neighborhoods. Effects are reduced when nearby neighborhoods are considered and are reduced even more when the neighborhoods are more distant.

Consequently, although neighborhoods can be of any size at the discretion of the exercise designer, there is an implicit assumption that neighborhood boundaries are more or less natural.

3.3 Input Rules and Models

The input rules detect when events, situations, or activities occur in the combat model that will cause changes in civilian or organization satisfaction levels. (Every activity that affects cooperation also affects satisfaction, though not necessarily in the same direction.) When this happens, a report is made available to ISM, which decides what and how to tell the training audience.

If an event, situation, or activity is not modeled explicitly in the combat model, it is called "abstract", though the effects *are* modeled explicitly in JNEM. They can originate in the combat model or be inserted by exercise controllers.

Version 3 of JNEM recognizes the following.

Events:

- Casualties to civilians or organization personnel
- Captures of hostile civilians
- Assassination, kidnapping, hijacking, bombing (these are hostile missions generated by JNEM)
- Facilities damage (of about two dozen kinds)

Situations:

- Contaminated food or water
- Communications outage
- Disease or epidemic
- Food, water, or fuel shortages
- Garbage in the street
- Industrial or sewage spills
- Damage to a mosque or other cultural site
- Unexploded ordnance
- Oil pipeline or refinery fires
- Power outage

Force group activities:

- Mere presence
- Patrolling
- Engaging in combat
- Enforcing a curfew
- Conducting interviews and screening
- Enforcing checkpoints or control points
- Establishing a cordon and searching an area
- Conducting psychological operations
- Conducting civil military operations (CMO): construction, light development, education, employment, support of industry, build or repair infrastructure, provide law enforcement, provide healthcare services, and, (of course) other
- Distribute supplies to civilians
- Engage in criminal activities or coercion

Organization group activities:

- Performing CMO-like operations: construction, education, employment, support of industry, build or repair infrastructure, provide healthcare services, other
- Distribute supplies to civilians

Civilian group activities are under development and may include rioting, striking, participating in festivals, etc.

Events cause satisfaction levels to change in a short period of time. Situations often have an initial effect, followed by a steady change as long as the situation continues, and a relieving effect at resolution. Activities often mitigate the bad effects of on-going situations.

Activities are constrained. When a unit is in combat, it cannot do anything else. When a unit is moving, some activities do not make sense. If security in a neighborhood is too low, some activities cannot be carried out successfully.

Each group's security in each neighborhood is computed from its strength in that neighborhood, the strengths of its friends and enemies, and the volatility of the neighborhood. A group's neighborhood strength is based on its population in the neighborhood, the strengths of the force groups to which it is related, and the strengths of its friends and enemies. Whether other groups are friends or enemies is based on the relationship matrix in that neighborhood.

3.4 Population Dynamics Model

The population dynamics model is a descendant of the *Regional Analysis Model* (*RAM*), which was developed for the U.S. Army National Simulation Center by the Department of Political Science at Texas A&M University, working with the George Bush School of Government and Public Service and the Texas Center for Applied Technology (both of which are also at Texas A&M). *RAM* was part of the *Spectrum* project to model biases, alliances, rivalries, and other aspects of inter-group relationships.

The population dynamics model receives changes in satisfaction and cooperation for the neighborhood group that was directly affected by whatever triggered the input model rule. Then, as described above, it uses the relationship matrices and "near" and "far" multipliers based on what happened to sort out the effects on all of the other groups. Effects in other neighborhoods are delayed by an amount that depends on which two neighborhoods are involved. (Cooperation will not show this delay—indeed, it will not be computed—for other neighborhoods until JNEM Version 4.)

Unspecified long-term trends, modeled as *a priori* constant rates, also contribute to changes in satisfaction.

Satisfaction levels range from "very dissatisfied" (a range of numerical values of –100 to –60) to "very satisfied" (ranging from +60 to +100). Simply accumulating the changes could easily go outside those limits if they were just added. Besides, there should be diminishing returns as either of the limits is approached. Both of these potential problems are resolved by considering the nominal changes to be percentages of the differences from the limits.

3.5 Output Rules and Models

JNEM creates a variety of reactive events, some of which are executed in the combat model, some within JNEM itself. Reactive event rates are adjusted by rules based on satisfaction levels, group demeanors, and other factors. Simulated events are randomly generated as Poisson processes.

JNEM controls how many people in each civilian group are hostile toward coalition forces on a playbox-wide basis. The fraction of the total population is based on the group's *mood*, then modified by a number drawn from a table of *demeanor* vs *satisfaction with autonomy* (*AUT*). With current data values, the modifier ranges from 0.01 (*AUT = Very Satisfied* and *Demeanor = Apathetic*) to 3.0 (*AUT = Very Dissatisfied* and *Demeanor = Aggressive*). The base percentage is also data driven, but it depends on a technicality of the exercise design (specifically, the portion of the population that were put into explicit units for use in the combat model). There are two kinds of hostile units, supporters and combatants. Combatants are made available to exercise controllers for use as combat forces.

JNEM assigns hostile missions to hostile combatants by a similar process: *mood* produces a base rate that is modified by a table of *demeanor* vs *AUT*. AGGROE (aggressive rules of engagement, that is, "shoot at anyone") missions are executed in the combat model and are directed at coalition forces by selection of a hostile unit that is near a coalition unit. The other hostile missions—assassination, hijacking, kidnapping, and terror bombing—are executed in JNEM itself; they are recognized by the input rules and their effects are tracked. Hostile missions are scheduled in advance so exercise controllers can intervene.

Numerical civilian satisfaction levels are a modeling artifact and are not given directly to the training audience. Rather, those levels are reflected in civilian activity reports whose narrative content and distribution are controlled by ISM, These reports are produced on a neighborhood-by-neighborhood basis.

Similarly, organization satisfaction levels are used to generate organization activity reports.

Neighborhood-by-neighborhood civilian cooperation levels are used to produce civilian information reports. The rates are modified by the presence of force groups and by what they are doing. Since cooperation is modeled by a civilian-group-to-force-group matrix, rates are also computed on that basis. Since JNEM has very little actionable intelligence information to transfer—just locations and missions of hostile units, ISM is again responsible for providing content, drawing on its database for additional intelligence nuggets.

4 INDEPENDENT STIMULATION MODEL

The Independent Stimulation Module (ISM) provides an interface to JNEM for the technical controller and for the training audience. The technical controller uses this feature to modify events, situations, and activities, if required to meet exercise objectives. For example, if the exercise director decides to add an additional refinery fire to the scenario, the refinery fire situation can be inserted in real time using the ISM exercise control interface.

ISM also controls the output of messages to the trailing audience, working in concert with JNEM. When JNEM sends an interaction to generate a civilian information report, it specifies the intended recipient, the information supplier (a civilian group) and the location of the supplier. Upon receipt, ISM searches its local data store for intelligence information germane to the specified location, such as the location of an improvised explosive device (IED). ISM then combines the data received from JNEM with its own data and composes a free text, human-readable message. The message is then sent to a specified training audience recipient as email.

5 FUTURE DIRECTIONS

5.1 Use in Other Regions

Considerable effort and attention has been given to making JNEM as broadly applicable as possible. Wherever possible, data, whether numbers, labels, or narratives, are obtained from databases. The magnitudes of modeled effects can be controlled by data-driven dials or even turned off by data-driven switches. Group names, characteristics, and relationships are defined by values in databases.

The people who live in different regions than are in current databases generally have different characteristics and belong to different groups, but all of this information is described by data, not hardwired into the computer program codes. To the extent they place different importance on the concerns contained in the current version of JNEM, those numbers can be adjusted by changing their *saliencies* for the concerns. When things happen, the magnitudes of the effects on satisfaction and cooperation are controlled by data.

Thus, just as the combat models can be applied in widely different regions if provided with large amounts of information about the physical terrain, so can JNEM, but it needs to know a lot about what could be called the "human terrain".

To the extent that people in other regions may have different concerns altogether, further development will be required to relate things that happen to the changes they cause in civilians' satisfaction levels. However, it should be noted that the current set of concerns—autonomy, safety, culture, and quality of life—are very fundamental. *Justice*, for example, is a component of *quality of life*, and both *liberty* and *freedom* may be synonyms for *autonomy*.

5.2 Normal Development

JNEM is a young model and can be expected to grow and develop in response to users' needs as described in Section 3.1. In particular, the model needs to be extended to cover longer planning horizons.

5.3 Use with Longer Planning Horizons

Mission readiness exercises currently run in real time for a week-long period, which was suitable for training in a cold-war operating environment.

The current operating environment, on the other hand, forces use of a much longer planning horizon. Actions taken by the training audience will continue to have effects weeks, months, even years after they are taken.

JNEM enriches training by considering the effects of everything that happens on the civilians' states of mind. With a longer time horizon, civilian states of mind are not enough; commanders must consider politics, the use and effects of diplomacy, and the economic consequences of their actions.

6 SUMMARY

As roles and missions evolve to meet new situations and operational environments, the Army's approach to training and readiness must also evolve. Rather than making major overhauls of existing tools, the services' approach has historically been to add major new functionality through external software modules that interface with the core combat models (Henry 1994). The addition of JNEM and ISM to the existing suite of tools demonstrates the effectiveness of this approach in response to rapidly changing requirements.

This new software has supported several mission readiness exercises, in preparation for deployment of U.S. forces into current theatres of operations, as described in Section 2.1 (above). It will continue to evolve and grow as required by current and future missions.

ACKNOWLEDGEMENTS

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, Booz Allen Hamilton, and the MITRE Corporation and was sponsored by the U.S. Army Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI), in Orlando, FL. The authors thank PEO STRI for its support for this research and acknowl-

edge the contributions of the Army's National Simulation Center at Fort Leavenworth, KS.

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REFERENCES

Gurr, T. R. 1970. *Why Men Rebel*. Princeton, NJ: Princeton University Press.

Henry, H. 1994. The Corps Battle Simulation: Remodeling the model for new missions. In *Proceedings of the 26th Conference on Winter Simulation*, ed. M. S. Manivannan and J. D. Tew.

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