

Converting the JNEM training aid to a forecasting tool

**A Monograph
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Abstract

CONVERTING THE JNEM TRAINING AID TO A FORECASTING TOOL by MAJ Royal S Ripley, Army, 91 pages.

The Joint Non-Kinetic Effects Model (JNEM) is a computer based simulation for training Division and Corps Commanders and Staffs in a manner that accurately replicates the complexities of interacting with civilian populations. The model replicates many of the dynamics that can affect the 'mood' for a given population along four different axis: Safety, Autonomy, Quality of Life, and Culture. The model replicates the myriad interactions that occur between population groups, enemy groups, and Coalition forces. By paying attention to these dynamics, the training audience can gain considerable insight and enjoy a much richer training experience prior to employing those skills in real life situations.

This monograph poses the question that if the model is considered accurate, such that inputs by the training audience generate accurate and reasonable outputs in the form of population reactions, then could the model be modified in order to serve as a forecasting tool for Campaign Designers. Similar to a weather model, which is updated on a daily basis, could JNEM take 'real-world' inputs and generate reasonably accurate forecasts for a population's mood? This would not be an effort to predict the actions of a particular individual, but an effort to give indications and warning that a particular area was headed for trouble.

Beginning with an introduction to Chaos and Complexity theories, the monograph examines the JNEM model for the potential to convert it from a training aid to a forecasting tool. The monograph concludes that JNEM, while structurally sound, isn't suited as a forecasting tool for the following reasons: its use as a training aid, the use of implicit versus explicit assumptions regarding causation, the use of arbitrary values, the use (or lack thereof) of feedback to refine equations, and the concept of emergence.

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Introduction

Mankind has always struggled with predicting the future. Whether it is weather forecasting, or planning for the future actions of an enemy, decision-makers strive to make better decisions based upon expected outcomes, using better predictive tools. The genesis of this monograph is that, within the realm of military operations among large and diversified populations, we should have better tools available for forecasting the moods and reactions of a populace prior to and concurrent with conducting operations. Essentially, we need a model that can perform forecasting of the human weather system. The relevance of such a model should be self-evident to military planners and Campaign Designers. Such a model would be beneficial in identifying trouble areas before they become truly troublesome. It could serve as an additional data point to give indications and warning that a portion of a population is likely to cause trouble in the near future. Such a model could also have the potential to examine different courses of action (COA) with more quantitative analysis regarding population reactions to a particular policy. Currently, the only model that is available to US Army units (Corps and Divisions) that models large, diversified populations is the Joint Kinetic-Effects Model (JNEM).

The Joint Non-Kinetic Effects Model is “a training simulation for brigade, division, and corps commanders designed to immerse them in a Stability and Reconstruction Operations (SR&O) environment where civilians and civilian groups are the key terrain, and some groups emerge as centers of gravity.”¹ The JNEM model is a training tool to help US military commanders and staffs understand the interaction of “competing civilian groups who have differing satisfaction/ dissatisfaction level towards each other, common concerns and intervening forces. Satisfaction levels change in response to civilian group and assorted force group activity,

¹ Joe Provenzano, *Interview*, ed. Ripley, Royal S. MAJ (Fort Leavenworth, KS:, 8 April 2008)

including criminal groups, within neighborhoods.”² Currently, the JNEM model is constructed to model the ‘playbox’ of Iraq and Afghanistan, though the designers acknowledge that it could just as easily be modified to model any country for which the US Army wished to create a training environment.³

The research question of this monograph poses the premise ‘Can JNEM serve as an effective forecasting tool for Campaign Designers, Planners and Commanders?’ If the JNEM model is considered accurate, such that its outputs to various inputs by the coalition force will result in plausible and accurate reactions by the population, then it is possible to develop a model which can be useful for ‘forecasting’ future levels of population cooperation, opinion or tendencies. The concept is that the model could take the daily moves, actions and responses of a coalition force and then show a forecasted change in population perceptions. According to John Holland, noted researcher and computer scientist, “Every time a scientist constructs a set of equations to describe the world...he is constructing a model. Each model concentrates on describing a selected aspect of the world, setting aside other aspects as incidental. If the model is well-conceived, it makes possible prediction and planning and it reveals new possibilities.”⁴ It is presumed the model would have to start with a period of ‘learning’ such that feedback from real-world outcomes informs the model in changing the values assigned to rules and variables.⁵ Eventually, the model is refined or ‘trained’ to make correlated predictions to actual inputs. It is acknowledged that such a model could not make precise predictions for all the vagaries of the real world (just as science can only predict the weather so far in advance). However, just as the

² Ibid.

³ Ibid.

⁴ John H. Holland, *Emergence: From Chaos to Order* (New York, NY: Basic Books, 1998), 4-5. John Holland is a Professor of Psychology and Professor of Electrical Engineering at the University of Michigan. He is considered by many to be the “father of genetic algorithms.

⁵ Ibid.

weather can show a certain probability of an event occurring (such as rain), the model may also be able to show the likelihood of a certain response based upon the input. The thesis of this monograph is that as currently constructed JNEM cannot perform this function.

Methodology

The monograph begins with a review of Chaos and Complexity theories and some of the major components that comprise this body of knowledge. This is followed by a review of the inner workings of the JNEM model and how its various rule sets are activated based upon the inputs to the model. This requires a fairly detailed understanding of how the various modules internal to JNEM function and how they determine levels of output. While the JNEM model does use a lot of abstract math in order to calculate results, the monograph is confined to a 'logical' description of those equations. It is important to note there is a distinction between 'JNEM-in-theory' and 'JNEM-in-practice.' JNEM in theory is the information culled from the JNEM Analyst's Guide, along with other documentation regarding the structure and rule sets of JNEM's modules. JNEM in practice refers to how JNEM is implemented by the National Simulation Center (NSC) and Battle Command Training Program (BCTP) at Fort Leavenworth, Kansas. JNEM in practice is the information gathered from discussing JNEM's implementation with personnel from NSC and BCTP. The next step in the methodology was to look for inconsistencies in the rule sets based upon a limited study of various social science theories covering the dynamics of population interactions in an environment characterized by violence. To this end, the monograph utilizes various books and texts such as 'Understanding Civil War', 'The Logic of Violence in Civil War', and 'Issues and Methods in Comparative Politics', 'Philosophy of Social Science', 'Democracy Challenged', and 'States, Ideologies, and Social Revolutions'. The third step in the methodology was to examine the JNEM model for consistency with regard to Chaos and Complexity theories. To this end, various aspects of the JNEM model appear to 'side-step' the problems associated with dynamical systems by assigning arbitrary values to a few

parameters in order to get the model to function correctly or with greater consistency. Some of this is related to the ‘training tool’ value of the model, but could potentially limit the ability of the model to serve in a correlated analysis capacity.

Chaos & Complexity Theories

Edward Lorenz is a research meteorologist who is generally credited as one of the ‘discoverers’ of Chaos and coining the term, ‘the butterfly effect’. Generally he is considered among the first people to recognize and demonstrate the phenomenon of Sensitive Dependence on Initial Conditions (SIC). He stumbled upon this realization in his efforts to build a model to simulate weather. Despite his best efforts and the use of computers to build effective simulations, the element of Chaos underlined his whole system. From that he realized the futility of trying to make detailed predictions about future weather conditions and concluded the “consequence of sensitive dependence is the impossibility to make perfect predictions, or even mediocre predictions sufficiently far into the future.”⁶ Current efforts to model the weather are limited in accuracy to about three days in the future. This isn’t due to a lack of detail in weather models or the collection of data points. In 1985, the European Centre for Medium Range Forecasts built a model for weather prediction. This effort was to represent the state of the art for weather prediction at the time. Medium range was defined as 10 days in the future. It was recognized that the weather, despite being a complex, dynamic system, was still a deterministic system, such that the state of future weather conditions was determined by the current state. In essence, by taking measurements of the current state, and knowing the way that the variables interacted with each other, this would deterministically yield the future states. The model that the European Centre

⁶ Edward Lorenz, *The Essence of Chaos* (Seattle, WA: University of Washington Press, 1993), 12.

built was based around three physical quantities: temperature and two wind components measured at 19 different elevations. Water-vapor content was also defined at all but the highest elevations, as well as soil moisture as appropriate. Finally, the model examined 11,000 points around the globe in order to generate a model of over 800,000 variables. By 1991, the model had been improved to include 45,000 points around the globe at 31 different elevations. This resulted in a model of over 5,000,000 variables. Interestingly enough, this order of magnitude in fidelity did not result in more accurate predictions by the hoped for '2 weeks' of time. Instead, the model's improvement was only measured in 'hours'.⁷

So, while the SIC phenomenon prevents making accurate long-term predictions, it doesn't prevent making predictions altogether. Efforts to model the weather can provide some useful insights to the problem of building accurate simulations of complex, chaotic systems. As John Holland notes,

Because meteorologists do not know the values of all the relevant variables, they do not work at a level of detail, or over time spans, in which chaos would be relevant. The predictions work with large masses of atmosphere over short time spans; so the butterflies, or jet airplanes, produce negligible effects. Moreover,...meteorologists start anew each day, using the most recent data. These observations continually bring the state of the model into agreement with what have actually occurred. Under this regime chaos theory has little relevance.⁸

Each iteration of weather sampling leads to a further refinement of the next day's weather forecast. In theory, any model (JNEM included) could work in very much the same way. However, there is a crucial difference, which is the amount of control over inputs. In the weather model, man is presumed not to control the inputs (aside from occasional attempts at cloud seeding or Indian rain dances.) This is contrasted with other models such as JNEM where the coalition forces and the choices they make control a large number of the input variables. This allows more

⁷ Ibid., 101.

⁸ Holland, *Emergence: From Chaos to Order*, 44.

influence over potential outcomes. Much of this is rather intuitive, however, the difference here is that there could be a more ‘scientific’ (objective) view as to the outcomes of actions prior to them being taken.

The analogy is that the model could function in a manner similar to the manner we use to forecast weather today. In current weather models, the problem of prediction is associated with Sensitivity to Initial Conditions (SIC) such that small variations in the accuracy of measurements can lead to large variations in predicted outcome as the predictions progress farther and farther into the future. Weather models today cope with this phenomenon through the use of *Monte Carlo forecasting*⁹ or Ensemble forecasts.¹⁰ Instead of building an extremely accurate model that is run once, a simpler model is run dozens of times with small variations in the inputs.¹¹

“The Monte Carlo procedure can give some idea of the degree of confidence to be put in a particular day’s forecast. If the separate forecasts show little resemblance to each other, the confidence will be low, whether one of the forecasts is selected arbitrarily as the official one or whether some average is used. If the forecasts are much alike, any one of them is likely to be fairly good.”¹²

In an overly simplified manner, if the output of the model results in precipitation in 30% of the dozens of runs, then the weather forecasters can make a correlation that there is a 30% chance of rain in the next 24 hours (and a corresponding 70% chance that it won’t rain). The analogy for the JNEM program is that it could be akin to a Human-Weather-system forecaster. By continually tracking the inputs and utilizing an ensemble technique, the program could become a tool for informing Commanders and campaign designers.

⁹ Lorenz, *The Essence of Chaos*, 103.

¹⁰ Leonard Smith, *Chaos: A Very Short Introduction* (Oxford, England: Oxford University Press, 2007), 138.

¹¹ Ibid., 138.

¹² Lorenz, *The Essence of Chaos*, 103.

The obvious critique of this approach is that the weather and a human population are completely unrelated systems. The weather system is clearly dynamic, but arguably ‘deterministic’ such that the current state of the system determines all future states. Clouds don’t make conscious choices about when to rain. This contrasts with a social system (particularly one with a determined enemy) and the problem is confounded by individual actors making individual choices, particularly the enemy actors who are ‘choosing’ to alter a system to their liking. Human social systems are characterized by many as ‘Complex Adaptive Systems’ (CAS) and governed by rules associated with Complexity.

Defining a Complex System can be a challenging proposition. A complex system according to Robert Axelrod and Michael Cohen in *Harnessing Complexity* is “when there are strong interactions among its elements, so that current events heavily influence the probabilities of many kinds of later events.”¹³ Perhaps a better definition comes from Yaneer Bar-Yam in *Making Things Work*, “Complex Systems is a new approach to science, which studies how relationships between parts give rise to the collective behaviors of a system and how the system interacts and forms relationships with its environment.”¹⁴ A complex system in of itself is defined as “...a system formed out of many components whose behavior is emergent, that is, the behavior of the system cannot be simply inferred from the behavior of its components. The amount of information necessary to describe the behavior of such a system is a measure of its complexity.”¹⁵ If this sounds very similar to Chaos Theory, in the sense of different things interacting with lots of other things, it is because the two fields of study are closely related, and share some similar academic roots, such as a multi-disciplinary approach and the use of non-linear mathematical

¹³ Robert Axelrod and Michael D. Cohen, *Harnessing Complexity Organizational Implications of a Scientific Frontier* (New York, NY: Basic Books, 2000), 7.

¹⁴ Yaneer Bar-Yam, *Making Things Work* (Cambridge, MA: NESCI Knowledge Press, 2004), 24.

¹⁵ Yaneer Bar-Yam, *Dynamics of Complex Systems* (Reading, Massachusetts: Addison-Wesley, 1997), 10.

functions. The difference is that while Chaos is usually associated with systems that are low-dimensional, deterministic, and have fixed transformation rules; Complex Adaptive Systems are usually associated with high dimensionality, non-deterministic, and are capable of learning/evolving.¹⁶ The term Complex Adaptive System (CAS) is derived from a study of Complexity and refers to “when a system contains agents or populations that *seek* to adapt.”¹⁷ Complex systems science has three major components: pattern formation, multi-scale analysis and dynamics. Pattern Formation consisting of: Self-Organization, Collective Behavior, Networks; Multi-scale analysis consisting of: Hierarchy theory, Emergence, Complexity profile, Universality; and Dynamics consisting of Adaptation, Attractors, Feedback, and Evolution. Key Complex Systems concepts include: Complexity, Adaptation, Self-Organization, Emergence, Autonomous Agents, Phase Changes, and Networks. While not all of these concepts are germane to a critique of JNEM, the following concepts will be described briefly: Emergence, Adaptation, and Feedback.

Emergence according to Alex Ryan is “the process whereby the assembly, breakdown, or restructuring of a system results in one or more novel emergent properties.”¹⁸ An important component of emergence is the concept of self-organization, which is a dynamic process in which a pattern at the global level of a system emerges solely from the interactions among lower level components of the system. As David Batten points out, “A mysterious process called self-organization can transform disordered, incoherent systems into ordered, coherent wholes. What’s even more amazing is that each emergent whole could not have been anticipated from the

¹⁶ Alex (Dr). Ryan, *Interview*, ed. Ripley, Royal S. (MAJ) (Fort Leavenworth, KS:, 11 June 2008)

¹⁷ Axelrod and Cohen, *Harnessing Complexity Organizational Implications of a Scientific Frontier*, 7.

¹⁸ Alex Ryan, "Emergence is Coupled to Scope, Not Level." *Complexity Journal* Volume 13, no. 2 (4 December 2007): 73. A ‘novel emergent property’ is further defined as “a property that if and only if

properties of the individual elements. Order from incoherence.”¹⁹ Additionally, the rules governing these interactions are executed on local information rather than referring to the global pattern. Recognizing the global pattern can also be a challenge but we are aided by our ability to interpret behavior.

Adaptation is “changes in behavior, structures and functions which improve success in the environment”.²⁰ Of course this presupposes that an entity has some definition of success, failure, or fitness relative to the environment, but the point is that the entity or agent has the ability to change itself, whether that is a plant growing in the direction of a window, a chess program that can change its internal weighting of rule sets based upon ‘success’ against a particular opponent, or human populations which adopt different strategies in order to enjoy greater ‘success’ in their environment. Variation is considered a key component to adaptation, such that some internal detail of the entity can exhibit variety. This along with a selection process that allows the entity to retain or discard variations as measured against the definition of fitness, brings us to the importance of feedback.

Feedback is the function that allows Adaptation to occur in an agent. Feedback is the process in which an entity takes information from the environment and assesses it against its internal model. This allows agents to judge variation in terms of adopting competing strategies for success. In other words, it is what allows a system to ‘learn’ about its environment.

The importance of these three concepts is that they are crucial to understanding Complex Adaptive Systems with regard to modelling. In order to accurately model CAS-type systems, the model itself should reflect a certain degree of CAS-like behavior.

that it is present in a macrostate but it is not present in any microstate, where the microstates differ from the macrostates only in scope.”

¹⁹ D. F. Batten, *Discovering Artificial Economics: How Agents Learn and Economies Evolve*. (New York: Westview Press, 2000), 31.

²⁰ Ryan, *Interview*

CAS systems in turn are governed by rules of non-linearity. As Tom Czerwinski points out in *Coping with the Bounds*, “Nonlinearity, which covers such concepts as chaos theory and complexity theory, does not conform to those qualities found in linearity. It is not proportional, additive, or replicable, and the demonstrability of causes and effects are ambiguous.”²¹ Thus Czerwinski concludes:

Fundamental to an understanding of nonlinearity is an understanding of complex adaptive systems, or CAS, which are the “engines” that drive nonlinearity. Complex adaptive systems are quite different from most systems that have been studied scientifically. They exhibit coherence under change, via conditional action and anticipation, and they do so without central direction. At the same time, it would appear that CAS have lever points, wherein small amounts of input produce large, directed changes. It should be easier to discover these lever points if we can uncover general principles that govern CAS dynamics. Knowing more about lever points would, in turn, provide us with guidelines for effective approaches to CAS-based problems.²²

It becomes apparent then, that at least from Czerwinski’s perspective, that if a sufficient understanding of a system can be generated, and the lever points identified, then a measure of control over such a CAS-based system can also be achieved. However there are those that point out that this thinking is flawed, as groups of human beings are more than just Complex Adaptive Systems.²³

Some social scientists would argue that the concept of individual free-will altogether precludes any possibility of prediction or forecasting of a collective pattern. Since every individual is making presumably rational choices based on their own preferences, values or desires, all of which are private and opaque to the modeler, then there is no way to create a model that predicts what those choices will be. What is rational for one person can be perceived as

²¹ Thomas J. Czerwinski, *Coping with the Bounds: Speculations on Non-Linearity in Military Affairs* (Washington DC: National Defense University, 1998), 2.

²² Ibid., 12.

²³ Ryan, *Interview*

completely irrational for another. This implies that any model that contains ‘rational’ choices will probably be necessarily wrong, as one can never be sure of the vagaries in human decision making. The critique of this argument is that the social scientists are conflating two different scales in the system.²⁴ They are confusing the problem of individual choice (at the smallest scale) versus the ability to detect emerging order from disorder (at a larger scale). So, while the social scientist criticism is accurate, it is also somewhat irrelevant. The model is not trying to predict individual choices, but instead attempting to forecast collective patterns.

Additionally, in the world of CAS-based systems further complexities are introduced which complicate the effort to make any forecasts at all. From Robert Jervis, in *Complex Systems: The Role of Interactions*, “We can never do merely one thing.”²⁵ Each and every action ends up impacting other variables, beyond the ones we intend to change. Jervis goes further,

Intuitively, we often expect linear relationships. If a little foreign aid slightly increases economic growth, then more aid should produce greater growth. But in a system, a variable may operate through a nonlinear function. That is, it may have a disproportionate impact at one end of its range. Sometimes even a small amount of the variable can do a great deal of work and then the law of diminishing returns sets in, as is often the case for the role of catalysts. In other cases very little impact is felt until a critical mass is assembled. For example, women may thrive in a profession only after there are enough of them so that they do not feel like strangers.²⁶

Jervis goes on to identify three types of interactions which bear upon the problem: 1) Interactions in which the Results cannot be Predicted from the Separate Actions - The effect of one variable frequently depends on the state of another, as we often see in everyday life: each of two chemicals alone may be harmless but exposure to both could be fatal; patients have suffered from taking combinations of medicines that individually are helpful. 2) Interactions in which

²⁴ Ibid.

²⁵ David S. Alberts and Thomas J. Czerwinski, ed. *Complexity, Global Politics, and National Security*, (Washington, DC: National Defense University, 1999), 48.

Strategies Depend on the Strategies of Others - Further complexities are introduced when we look at the interactions that occur between strategies when actors consciously react to others and anticipate what they think others will do. 3) Interactions in which Behavior Changes the Environment - Initial behaviors and outcomes often influence later ones, producing powerful dynamics that explain change over time and that cannot be captured by labeling one set of elements “causes” and another “effects.”²⁷

Despite all these difficulties, there are those scientists that maintain that Chaos and Complexity is not beyond a level of prediction and therefore control. From the theoretical point of view, Leonard Smith illustrates, “Chaos poses no prediction problems for Laplace’s Demon: given exact initial conditions, a perfect model and the power to make exact calculation, it can trace a chaotic system forward in time as accurately as it can a periodic system.”²⁸ Of course, Laplace’s Demon was a mythical creature used to illustrate Laplace’s concepts that the world was completely deterministic and therefore devoid of free-will. However according to more contemporary and practicing scientists Alfred W. Hubler, Glenn C. Foster, and Kirstin C. Phelps, in ‘*Managing Chaos*’ published in Complexity Journal.

More precisely, long-term predictions of deterministic chaos are hard, because even very small amounts of noise can change the motion significantly. Short-term predictions and even medium-term predictions of chaos are not that difficult, because the motion is governed by a deterministic equation, plus some small noise. In contrast, controlling the chaotic motion of an agent is often easy, both short term and long term. Just apply a control force that is equal to the difference between the next state of the agent and the target, and it will go to the

²⁶ Ibid., 51-52.

²⁷ Ibid., 53-62.

²⁸ Smith, *Chaos: A Very Short Introduction*, 123. Pierre Simon de Laplace (1749-1827) was a French mathematician and astronomer who produced the first definitive formulation of the theory of probability. According to Laplace, probabilities arise from our ignorance. The world is deterministic, so the probability of a possible event depends on our limited information about it rather than on the causal forces that determine whether it shall occur.

target. This requires predicting the next state, which is a short-term prediction and therefore is possible for chaotic agents.²⁹

However, even those authors acknowledge the theoretical challenges associated with predicting and controlling chaotic agents in social organizations. Still they remain undeterred.

Long-term prediction of uncontrolled chaos is virtually impossible in large networks of chaotic agents. However, it appears to be possible to switch such networks to controlled chaos, which makes them predictable, without losing the benefits of chaotic systems. Even though the dynamics of social organizations are much more complicated than these simple chaotic models, it is conceivable that a similar approach can be used to predict and control them.³⁰

In addition, Robert Axelrod points out that prediction for social sciences are difficult but not impossible.

In the social sciences in particular, even highly complicated simulation models can rarely prove to be completely accurate. Physicists have accurate simulations of the motion of electrons and planets, but social scientists are not as successful in accurately simulating the movement of workers and armies. Nevertheless, social scientists have been successful in using simulation to discover important relationships and principles from very simple models.³¹

In terms of practical advice, Axelrod also offers

Since virtually all social science simulations include some random elements in their initial conditions and in the operation of their mechanisms for change, the analysis of a single run can be misleading...it is necessary to do several dozen simulation runs using identical parameters (with different random number seeds) to determine which results are typical and which are unusual.³²

Remarkably, this is the same approach used by the weather forecasters, but applied to a social system.

²⁹ Alfred Hubler, Glen Foster, and Kirstin Phelps, "Managing Chaos," *Complexity Journal* Volume 12, no. 3 (2007): 11.

³⁰ Ibid., 12.

³¹ Robert Axelrod, "Advancing the Art of Simulation in the Social Sciences," *Complexity Journal* Volume 3, no. 2 (1997): 17.

So, the monograph returns to the basic premise, which really breaks down into two questions: 1) is it possible to build such a model; and 2) is it feasible to build such a model of a human social system that even somewhat accurately forecasts the mood and dispositions of human populations in the real-world? The answer (and a hypothesis of this monograph) remains, yes, if the model is built well enough to accurately reflect the population under study, and if the model has the capability to ‘learn’ from experience, and the limits of the model are understood not to produce detailed predictions, but more of generalized forecasts based upon coalition inputs. The JNEM model then could become more than just an aid to learning, but a useful tool for forecasting.

The Joint Non-Kinetic Effects Model

JNEM is a simulation based training tool. According to the *JNEM Analyst’s Guide, Draft 11*, JNEM is designed to model civilian actions and reactions in order to provide a fuller, more beneficial training experience for Corps and Division staffs. “Commander must pay attention to the major population groups’ feeling, neighborhood by neighborhood, about safety, quality of life, and cultural and religious issues, just as they must in real life.”³³ JNEM is a federate (or program) running within a series of higher level federates. The Analyst’s Guide defines federation as, “..a *federation* is a collection of cooperating simulations and other applications. In this document, the term *federation* is also used to refer to the world simulated by the federation and external to JNEM, e.g., ‘events happening in the federation’.”³⁴ The other federates that JNEM expects to share in the federation include some sort of ground model, Exercise Control and

³² Ibid., 19.

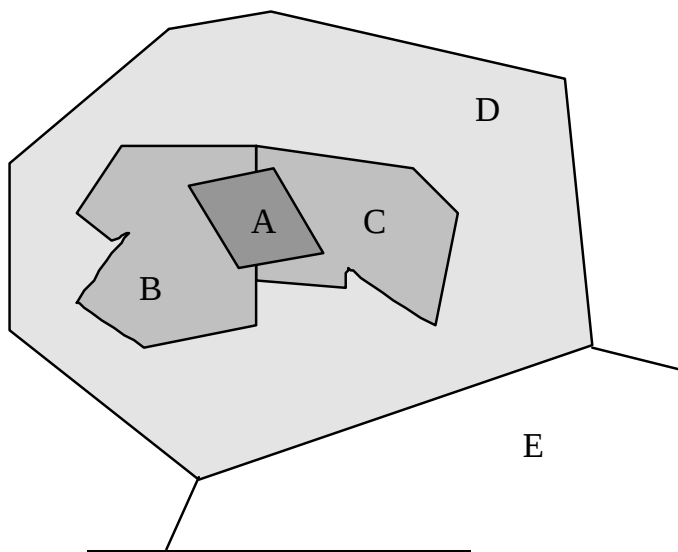
³³ William H. Duquette and Robert Chamberlain, *JNEM Analyst’s Guide* (California: Jet Propulsion Laboratory, 2008), 1.

³⁴ Ibid., 4. The two higher-level federates are the Joint Land Component Constructive Training Capability (JLCCTC) Multi-Resolution Federation (MRF) and the JLCCTC Entity Resolution Federation (ERF).

Informational modules, and a Basic Encyclopedia Server (BE Server). The ground model can be one of several commonly used platforms used to simulate military and civilian units. This is where the training audience gets to move their pucks around on the ‘battlefield’. The Exercise Control module is used by exercise controllers to inject inputs and view outputs by JNEM. The Informational module is the Independent Stimulation Module (ISM), which is used to generate informational messages and forwarding them to the training audience. The BE Server tracks damage to fixed sites. By monitoring the BE Server, JNEM can create abstract situations in response to facility damage. In the end, JNEM is a very flexible tool for training due to its realism. “One of the strengths of JNEM is the ‘free play’ that it allows for very novel situations to develop based upon training audience interaction. As a training aid, this is considered superior to the Mission Scripted Event List (MSEL) typically used in most simulations.”³⁵

Space

Figure 1. Sample playbox demonstrating nesting.



Like any simulation, JNEM models population dynamics inside a defined space, or the ‘playbox’ in this case. JNEM’s playbox is a geographic region divided into ‘neighborhoods’. “Neighborhoods are simply a way of dividing the

³⁵ Dale Atwood, *Interview*, ed. Ripley, Royal S. MAJ (Fort Leavenworth, KS:, 18 July 2008) Additionally, the training audience is never aware that they are playing in a JNEM simulation. They are aware of the pucking (the simulated movement of icons) going on in one the larger federation modules, but they never have any direct interaction with JNEM or are they even aware of the parameters. This is considered a good thing, to prevent a training audience from ‘gaming’ the system.

playbox into a number of reasonably homogeneous areas, and may be of any size: country, province, city, town, zip code, neighborhood proper.”³⁶ Another important aspect of the playbox is ‘nesting’, which is similar to the way that we view a city as nested inside a province, or neighborhoods inside of a city. JNEM treats nested areas as discrete regions for computation.

JNEM also accounts for the ‘ripple affect’ of events where an event that occurs in one neighborhood can have a similar, though weakened, effect in other neighborhoods. This is done by assigning a level of proximity or the *neighborhood proximity*. The four proximity levels are defined as: here, near, far and remote.³⁷

In practice, the Political, Military, Economic, Social, Information, and Infrastructure (PMESII) cell in the Exercise Control (EXCON) group of BCTP is responsible for determining how the neighborhood boxes and groups will be portrayed in the simulation. This can be a rather arbitrary process as it is the point in time when a judgment call must be made as to what constitutes a neighborhood and the initial satisfaction levels inside that neighborhood. In order to ensure a level of realism, BCTP relies on information provided from the Training and Doctrine Command (TRADOC) Intelligence and Support Activity (TRISA) in the form of country studies. This information is provided to the PMESII cell in the EXCON in order to build the initial settings for the simulation. “BCTP’s largest concern is not necessarily creating a playbox that is 100% accurate, but one that meets the requirements laid out by the exercise director for that particular iteration of the simulation.”³⁸ Currently, the PMESII cell utilizes two main criteria of

³⁶ Duquette and Chamberlain, *JNEM Analyst's Guide*, For example, if neighborhood D completely enclosed neighborhood B, then effectively B has cut a hole in D for the purpose of computing various values and results. Neighborhood B is treated as a discrete element from neighborhood D.

³⁷ Ibid., 5. Using the diagram above, for neighborhood A, an event taking place in A would be categorized as ‘Here’. Neighborhoods B and C might view the event as ‘Near’. Neighborhood D could be categorized as ‘Far’ and Neighborhood E as ‘Remote’. Proximity is not determined by geographical distance alone, but by social distance. Additionally, JNEM can induce a variable delay between an event and the corresponding ripple effect for a neighborhood that is Near, Far or Remote.

³⁸ Eileen Pember, *Interview*, ed. Ripley, Royal S. MAJ (Fort Leavenworth, KS:, 18 July 2008)

population density and political boundaries to determine the size and shape of neighborhood boxes. However, the Deputy Chief of the PMESII Division, Mark DeMike, points out that it doesn't really matter how the neighborhoods are drawn, instead what matters are the relationships between the population groups in those neighborhoods.³⁹

The actors inside the playbox are the population groups. JNEM describes these actors by defining three basic sets of population groups: civilian groups, organization groups and force groups.

Groups

The Civilian groups are the ones that inhabit the playbox areas or neighborhoods. JNEM allows the population to be divided by “ethnicity, religion, language, social class, political affiliation, or any other demographic criteria the analyst deems necessary. Groups are similar to the ‘market segments’ used to target advertising: a group is a collection of people who may be assumed to have similar biases, interests, and behaviors due to their demographic similarity.”⁴⁰ JNEM then tracks the groups of civilians by neighborhood, referring to a specific civilian group in a specific neighborhood as a *neighborhood group*. Additionally, JNEM tracks that certain members of a population will form civilian units that can interact with other units in the larger federation of programs. Thus “some fraction of a civilian group’s units will be presumed to have become combatants, capable of committing terrorist acts, or supporters of combatants. The fraction will rise and fall depending on the mood of the group playbox wide, among other factors.”⁴¹ The ‘mood’ in this case is modeled by JNEM as composite of the satisfaction of each group in each neighborhood along several axes.

³⁹ Mark DeMike, *Interview*, ed. Ripley, Royal S. MAJ (Fort Leavenworth, KS.; 29 July 2008)

⁴⁰ Duquette and Chamberlain, *JNEM Analyst's Guide*, 6.

⁴¹ *Ibid.*, 6.

Organization groups are the groups “present in the playbox to help the civilians.”⁴² JNEM tracks three different types of Organization groups: Non-Governmental Groups (NGOs), Intergovernmental Groups (IGOs) and Contractors (CTRs). NGOs are the ones typically doing humanitarian work, while IGOs are international organizations such as the United Nations (UN). Contractors are any commercial firm doing work in the playbox, usually but not always for the Coalition. Organizations also show up in the federation as ground units and have the ability to perform *activities* which can affect civilian satisfaction levels.

Force Groups are groups whose purpose to use force, such as military or militia forces. There are five types of forces: Regular military (US military), Paramilitary (SWAT teams and other combat-trained police units, Police (normal civilian police), Irregular military (militias), and Criminal (organized crime). US military units are associated with the BLUE force group and are referred to as such. The force group types are a way categorize the degree to which one force group is able to project force vis-a-vis another force group. As with the organization groups, force groups may perform a large array of activities that affect civilian satisfaction. Regarding the use of force in JNEM, each and every group (civilian, organizations and force groups) “have the ability and willingness to project and use force.”⁴³

Time

A note about time, as a simulation JNEM tracks time in discrete steps. Using *ticks* and *tocks* as minor and major time steps respectively, JNEM tracks events on a tick by tick basis.

⁴² Ibid., 6. Depending on the group’s capabilities, each organization group can perform medical, engineer and/or support activities. JNEM also tracks the willingness of an Organization group to perform work in each neighborhood. Thus each organization group will have a perspective as to the level of risk of performing work within each neighborhood. A group that perceives a neighborhood as low-risk might perceive a different neighborhood as high-risk and consequently be unwilling to enter that area.

⁴³ Ibid., 7. JNEM computes a balance of forces that takes into account population size and number of personnel in a neighborhood in order to determine the security level of each group in each neighborhood. This security level then determines what activities a particular group can perform, if any.

Every so many ticks equal a tock, in which “JNEM analyzes current status and computes the current satisfaction levels.”⁴⁴

Modules Overview

JNEM itself consists of three modules: the JNEM Input Module (JIN), the JNEM Regional Assessment Module (JRAM), and the JNEM Output Module (JOUT).

JIN

JIN is a rule based monitoring and assessment tool that monitors events from the federation’s combat simulations. “JIN is primarily concerned with detecting and assessing the implications of federation events and situations.”⁴⁵ An *event* in this case is something that happened at a particular time within the simulation, such as an exchange of gunfire where civilians are killed. There are two types of events in JNEM: *monitored events* and *abstract events*.

Situations are similar to events, but take place over a longer period of time, such as the presence of a unit, or an activity conducted by an organization. Again, there are two types, *monitored situations* and *abstract situations*. Monitored situations “involve the doings of force and organization groups in the federation.”⁴⁶ Abstract situations are things like power outages, food shortages, and contaminated water. Just as in real-life, the longer an abstract situation persists the more dissatisfied the civilian population will become. Ideally, the training audience

⁴⁴ Ibid., 10. Typically a tick is one minute in length while a tock is five ticks. The rest of the Federation programs use decimal hours, but the interface between programs converts the decimal hours to ticks.

⁴⁵ Ibid., 8. When an event takes place in the larger federation that is a monitored event. JIN looks for specific events occurring in the larger simulation which trigger a rule to be fired. Abstract events are ones that occur only in JNEM and are usually received from the ISM/EXCON cell. They don’t trigger a specific rule in JIN but pass straight through to the JRAM module. Abstract events can also be triggered by the JOUT module which creates events which are in turn monitored by the JIN rule sets.

⁴⁶ Ibid., 8. Some examples of monitored situations include the presence and activities of units, handing out supplies to civilians, the presence of a security checkpoint, conducting law enforcement activities, etc...

should learn to resolve these situations as quickly as possible. If some abstract situations persist long enough, they will cause new situations to arise, such as a sewage spill eventually causing disease.

Lastly, there is a special case of event or Hybrid which reflects damage to facilities. For example if a power plant is damaged (monitored event) it can trigger a related abstract situation such as a power outage (abstract situation) in the area.

JIN also does a small amount of modeling that can reflect changes in civilian satisfaction and cooperation. As military commanders conduct operations, attempt to use diplomacy, or support humanitarian aid and infrastructure building, these will have effects in the simulation on either the civilian population groups or groups of Non-Government Organizations (NGO's), International Organizations (IGO's) and contractors. Additionally, failing to act to address a situation can also have effects. As JIN is a rule based module, certain conditions will trigger the firing of a rule which produces an effect in the model. Additionally, JIN can also accept inputs from Exercise Control.

In practice, the training audience is never aware that they are playing in a JNEM simulation. They are aware of the 'pucking' (the movement of icons in the simulated battlespace) going on in one of the larger federation modules, but they never have any direct interaction with JNEM nor are they aware of the parameters governing mood or the various categories of abstract events.⁴⁷

JOUT

The JOUT module is the vehicle for translating effects back into the federation. JOUT accomplishes this by scheduling and executing *reactive events*. Reactive events can affect the

population either directly or indirectly, or result in some piece of information flowing to the training audience. Examples of JOUT events include exposing hostile units, or causing hostile units to commit acts of violence. JOUT is similar to JIN in that it uses rule-sets to determine when to trigger a response. “All reactive events are generated randomly at a rate of so many events per day; the rates are computed by JOUT’s rule sets and are based on the satisfaction and cooperation level computed by JRAM...”⁴⁸ The reactive events can occur immediately or be scheduled for later on.

JRAM

The JNEM Regional Analysis Model (JRAM) is the real core of JNEM. Its purpose is to model the population dynamics inside of JNEM and is “highly mathematical and highly abstract.”⁴⁹ JRAM consists of three components: the Civilian Satisfaction Model (CIVSAT), the Organization Satisfaction Model (ORGSAT), and the Group Cooperation Model (COOP). CIVSAT and ORGSAT share a common framework called the Neighborhood Satisfaction Model (NSAT). NSAT is the basic component of JRAM which computes the satisfaction level of different populations within each neighborhood with regard to each group’s concerns. NSAT also computes the changes (or slopes) for satisfaction levels as groups respond to the different events and situations within the federation. NSAT can then produce summary statistics for each neighborhood as well as for the entire playbox.

⁴⁷ Atwood, *Interview*. Hence, the training audience issues ‘orders’ for certain tasks to units without being aware of how those orders are translated into abstract activities. As a training tool, this is useful in order to prevent a training audience from ‘gaming’ the system

⁴⁸ Duquette and Chamberlain, *JNEM Analyst's Guide*, 9. Additionally, JOUT also determines the percentages for each civilian group’s units to become combatants or supporters of combatants. These percentages are determined by the JOUT rule sets, but are managed playbox wide instead of by neighborhood.

⁴⁹ Ibid., 8. JRAM is based on an earlier model, the Regional Analysis Model (RAM) which was produced for the National Simulation Center by the Political Science Department of Texas A&M

In summary, JIN and JOUT interact with JRAM which allows the JNEM model to translate simulated events into mathematical numbers for analysis and subsequently back into simulated events for the training audience.

NSAT

NSAT can be thought of in overly simplified terms as a ‘score-keeper’. Every group in every neighborhood essentially has a score of its level of satisfaction for a particular concern. This *satisfaction level* is a decimal number between -100 and 100. Each group in each neighborhood is tracked along four areas of *concern*. The current areas of concern for populations in NSAT are: Safety (SFT), Autonomy (AUT), Quality of Life (QOL) and Culture (CUL). NSAT produces a running total in each area depending on the inputs it receives. The *mood* (also known as a *composite satisfaction*) is the weighted average for the concerns for a particular group inside a particular neighborhood. The weighting of the scores (or *saliency*) reflect that different groups place different amounts of importance on different concerns. Additionally, as different groups come in different sizes and some groups have greater importance than others, NSAT introduces the factor of *rollup weight*, when averaging across groups or neighborhoods.

As NSAT is essentially just updating the ‘score’ as time progress, it traces a *satisfaction curve* over time. NSAT takes the current ‘score’ or satisfaction level at Tock 1, computes the various contributions from Tock 1 to Tock 2 and adds these to the Tock 1 score to produce a new score for Tock 2. It then repeats the process for Tock 3 and so on. These ‘contributions’ come from three sources: the contribution of *level effects*; the contribution of *slope effects*, and the effect of the *long-term trend*. Each of these different contributions is then scaled to reflect “the

University along with the George Bush School of Government and Public Service and the Texas Center for Applied Technology. A description of the specific mathematical equations is enclosed in Appendix III.

effects of diminishing return as the extreme values are approached.”⁵⁰ Mathematically, a long-term trend is just a constant number that produces a steady increase or decrease in a satisfaction curve. This allows JNEM to reflect a ‘propensity’ for a particular group in a neighborhood, that if left completely alone, a particular concern would grow better or worse without outside influence.⁵¹ A level effect is “a satisfaction change of a specified nominal magnitude which takes place over a specified period of time...Level effects are the result of independent events which affect the local civilian population and hence their satisfaction”⁵²

Compare a neighborhood which experiences a bombing with a neighborhood which experiences three geographically- separated bombing in a matter of minutes, and suppose the same number of civilians are killed in both neighborhoods. The civilians in the second neighborhood are likely to respond to the three bombings in much the same way as the civilians in the first neighborhood...In short, people’s capacity to respond to events, their ability to feel horror and dismay...can be saturated on a number of axes. Once their capacity is saturated due to events of a particular kind, further events of that kind occurring shortly thereafter are unlikely to have much additional effect.⁵³

In order to know which effects should be subject to level effects, JNEM must track the *causes* of each effect. Each input to NSAT can be assigned a cause. Similar inputs should have similar causes. This prevents multiple effects with similar causes from cascading out of control, by limiting their total contribution to the contribution of the largest effect.

Slope effects are very similar to level effects and are defined as “a satisfaction change with a specified nominal slope (change/day). The effect will cause satisfaction to change

⁵⁰ Ibid., 15. The importance of scaling becomes clear when looking at an example near an extreme. If a particular group was already near the highest level of satisfaction (a score of 100) then a further positive contribution should have less effect than if that same level of satisfaction was in the negative numbers. Thus, JNEM takes each nominal contribution and scales it according the current satisfaction level to produce a scaled contribution. See Appendix III for the equations governing scaling.

⁵¹ Francois Jullien, *A Treatise on Efficacy* (Honolulu, Hawaii: University of Hawai’i Press, 2004)

⁵² Duquette and Chamberlain, *JNEM Analyst’s Guide*, 16-18. A level effect essentially limits the amount of affect a number of similar events can have when they occur close to each other in proximity of time.

at that same nominal rate until its end time has been reached or the nominal contribution to date has reached a specified limit.”⁵⁴ A similarity between level effects and slope effects is the concept of a *limit*, which is an upper bound for the effect and defined when the effect is created. Similar to level effects, this is useful to keep multiple effects from cascading out of control, or forming a type of feedback loop on itself. This limit to effects also plays a part in determining how indirect effects affect the playbox.

To review, direct effects can take two forms: level effects or slope effects for a particular concern of a group in a neighborhood. As groups share neighborhoods, and neighborhoods share boundaries, JNEM allows for direct effects to have *indirect effects* on other groups of populations in the playbox. Indirect effects differ from the direct effects in two ways. First their magnitude (*limit* for level effects, *slope* and *limit* for slope effects) is adjusted by a multiplier which depends on the relationship between the two groups. Second, indirect effects that propagate outside of the originating neighborhood are delayed by an interval that depends on the relationship between the two neighborhoods.⁵⁵

⁵³ Ibid., 18.

⁵⁴ Ibid., 20. The difference between slope effects and level effects appear to be that while level effects are designed to deal with ‘events’, slope effects are meant to treat ‘situations’.

⁵⁵ Ibid., 24. This interplay of indirect effects requires that JNEM has a database (or table) that defines the magnitude of relationships between groups along with another matrix which defines the relationship between neighborhoods. Neighborhood proximity is defined by a proximity matrix with four categories of: here, near, far, and remote. This interplay of indirect effects requires that JNEM has a database (or table) that defines the magnitude of relationships between groups along with another matrix which defines the relationship between neighborhoods. Neighborhood proximity is defined by a proximity matrix with four categories of: here, near, far, and remote. One other note is that proximity is not always symmetric. If the residents of neighborhood A frequently visit neighborhood C and so regard C as NEAR; but if the residents of C seldom visit A, they may regard A as FAR. The magnitude multiplier is a series of variables that are used to define the indirect effect on particular group from a direct effect on a different group. Similar to the proximity matrix, they are defined in the JNEM database and provide multipliers for computing the indirect effects from the values of the direct effects.

In practice, there is a certain amount of arbitrary decision making in order to determine values assigned to initial slope and level effects. BCTP sets all of the ‘arbitrary’ data when a database is created for each new simulation. This includes defining the size of each neighborhood and initial satisfaction levels. In order to ensure a level of realism, BCTP relies on information from the TRADOC Intelligence Support Activity (TRISA) in the form of country studies. That information goes to the PMESII cell in EXCON which determines the actual numbers to be used.⁵⁶ The country studies themselves are generated by TRISA with the four variables of Safety, Autonomy, Quality of Life, and Culture in mind, along with suggested values for each variable. One note of importance is that BCTP’s largest concern is not necessarily creating a playbox that is 100% accurate, but one that meets the requirements laid out by the exercise director for that particular iteration of the simulation.⁵⁷ This is echoed by Ben Jordan at TRISA “Yes, the reports are crafted and even quantified (TRISA builds a database of initial numbers for all the variables) along with a recommended set of neighborhood boxes. However, BCTP can/will override those values in order to better meet the training objectives of an exercise.”⁵⁸

CIVSAT and ORGSAT

CIVSAT is the application of NSAT to the various civilian groups in the playbox. Though identified briefly earlier, the areas of concern for the civilian population are: autonomy, safety, culture and quality of life. Autonomy measures whether a group can govern itself and maintain order with a stable government and economy. Safety measures how a group feels about its safety, whether from attack from a hostile group or collateral damage from Coalition activities.

⁵⁶ DeMike, *Interview*

⁵⁷ Pember, *Interview*

⁵⁸ Benjamin Jordan, *Interview*, ed. Ripley, Royal S. MAJ (Fort Leavenworth, KS:, 7 August 2008)

This concern also includes other threats to safety such life-threatening disease, starvation, and dying of thirst. Culture is a measure of how well a group feels that its culture is respected or denigrated, including religious sites. Quality of Life focuses on all the physical plants that provide services, such as water, power, markets, hospitals and public transport. It also focuses other things associated with services such as food, shelter, sanitation, health, education, and employment.

ORGSAT is the same NSAT model, but applied to the various Organizations in the playbox. The concerns of organizations are just two: Casualties and Services. Casualties measure how dangerous ORG groups view the environment with respect to their member's willingness to risk their lives to do their work. Services is sort of like job satisfaction and measures how satisfied an ORG group is with the services they are providing to civilian populations.

Cooperation Model

The Cooperation model (COOP) is designed to model the probability of cooperation between groups. In practice, COOP is used to measure the probability of a member of a Civilian group providing intelligence to a Force group. While the model could be run between any two groups, it is limited to computing cooperation between CIV and FRC groups.⁵⁹

The presence and activities of FRC units is one of the factors that determine how COOP will determine the probability of cooperation. COOP determines the probability as a percentage per day change. So, if a FRC unit conducts a certain activity with regard to a population group that corresponds to a 10% change, then the probability of that CIV group

⁵⁹ Duquette and Chamberlain, *JNEM Analyst's Guide*, 30. The cooperation level is affected by: the presence of FRC units and activities, the presence of security checkpoints, and the distribution of supplies to civilian groups. The COOP model did not originate with JRAM and the rest of the JNEM modules, but derives from a methodology used by TRADOC HUMINT specialists.

cooperating goes up 10% each day. However, we know that reality doesn't allow for cooperation to be generated so easily. So, the value of the activity is modified by the *coverage fraction* and a Relationship Multiplier Function (RMF). The coverage fraction is a number that reflects the fraction of the neighborhood affected by the FRC unit activity, while the RMF reflects the nature (positive or negative) of the relationship between the two groups. The value of various activities in generating cooperation "is chosen by subject matter experts (SMEs) relative to a nominal relationship, and to a nominal coverage fraction (usually 2/3, or 0.66) specified in the model parameter database."⁶⁰ The concept of coverage fraction is an important tool but also highlights the importance in how neighborhood boxes are drawn. "There is always a risk of a neighborhood being drawn too large which causes havoc with the coverage fractions associated with force abstract activities. If we make the box too large, then the unit just gets swallowed up inside and can't have an effect."⁶¹ In practice, the BCTP PMESII cell relies primarily on population density and political boundaries in order to determine the size and boundaries of neighborhoods.⁶²

The distribution of supplies is a complicated and messy business in JNEM. In a very simplified form, supplies of a particular type are distributed to civilians through the interactions of three groups: the Donor group, the Distributing group, and the Recipient group. JNEM assumes that the transfer of supplies affects the likelihood of the receiver cooperating with the giver rather than vice versa. This creates three types of potential cooperation relationships: Type 1 – cooperation of distributor with donor, Type 2 – cooperation of recipient with donor, and Type 3 – cooperation of recipient with distributor.⁶³

⁶⁰ Ibid., 31.

⁶¹ Pember, *Interview*

⁶² DeMike, *Interview*

⁶³ Duquette and Chamberlain, *JNEM Analyst's Guide*, 32. Each type of cooperation relationship is further modified by a RMF along with a few particular rules to each type. Type 1 relationships (distributor to donor) are just about the transfer of supplies, and interestingly are not dependent on whether or not the distributor actually distributes the supplies to the civilian population. Type 2 relationships (recipient to

JIN

The following is a more detailed description of JIN and how it performs Neighborhood Force Analysis, Relationship Multiplier Functions, Force Presence and activities, Organization Activities, Facilities Damage, Distribution of supplies, and Security Checkpoints.

Neighborhood Force Analysis is measuring forces in neighborhoods. JIN is concerned with determining the *security*, *volatility*, and *force* for neighborhoods and the groups inside of them. Security is just a simple measure of a group level of security. That level of security in turn determines what kinds of activities the group can conduct within the neighborhood. Volatility is a measure of the likelihood of spontaneous violence within a neighborhood. Force is a measure of a group's ability to use force to control a neighborhood.

Starting with the measure of *force*, JIN determines amount of capability that a group possesses. A group can possess the ability to use force in the explicit form of units or the implicit form of its population. Additionally, friendly military units (as in those with a positive relationship) in the same neighborhood increase the level of force for a particular group proportionally to their size and activities.⁶⁴

donor) are dependent on whether the civilian population is actually consuming the donated supplies in regard to some situation. For example, donating water to a population that isn't suffering a water shortage won't engender a great deal of cooperation. Type 3 relationships (recipient to distributor) are also governed by the same limitation of the consumption of supplies by the civilian group. In all three cases, the variation of the values of different types of supplies with regard to engendering cooperation is determined by SMEs based upon a nominal relationship and nominal draw fraction, similar to the force activity coverage

⁶⁴ Ibid., 36. A civilian group's force is also affected by the presence of other friendly civilian groups, but by a smaller proportion per person than if those friendly civilians were soldiers or militia members. Civilian groups force is also affected by whether the group possesses an aggressive demeanor and bad mood. Friendly contractors can also contribute to an increase in a group's force. However, NGO's and IGO's (as neutrals) do not contribute. The last factor is the presence of friendly groups and units in adjacent neighborhoods. It is similar to calling for help from one's buddies in a bar fight. This same rule also applies to computing the force for a competing group in the same neighborhood. That competing group can also call for help from adjacent neighborhoods. One of the current limitations of JNEM is that it doesn't have the ability to differentiate between types of units (infantry vs armor vs field artillery) in computing force.

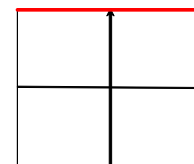
Volatility measures the likelihood of spontaneous violence. It “depends on the balance of forces in the neighborhood, and is a key component of security.”⁶⁵ Volatility is important to ORG groups and determining whether they will enter a neighborhood or not.

As stated earlier, security is a measure that determines that types of activities a group can perform in a neighborhood. By combining the measures of force and volatility, security is computed based upon the following general principles: the presence of friendly forces should increase security for a particular group within a particular neighborhood; the presence of enemy forces should decrease the level of security for that group; and increased volatility should decrease security for that group as well.

The Relationship Multiplier Function (RMF) is an attempt to capture the strength of relationships between groups for the purpose of computing the effects of various activities. In effect, it creates a multiplier for use in an equation that can strengthen or weaken the effect for a particular activity. Currently, there are seven types of RMFs: Constant, Linear, Quad, Friends Quad, Friends More, Enemies Quad, and Enemies More.⁶⁶

Figure 2. RMFs.

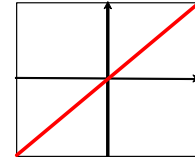
Constant Function - The Constant RMF simply returns a constant of 1.0 and in effect treats the activity as having no RMF at all, i.e., $(n \times 1 = n)$.



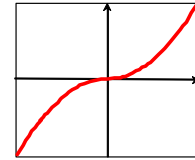
⁶⁵ Ibid., 40. Even if the ORG group is friendly with all the parties, the volatility of a neighborhood might preclude them from conducting activities if the chance of getting caught in the cross-fire is too high. The key component to measuring volatility is the total number of individuals potentially involved in conflicts compared to the total population.

⁶⁶ Ibid., 42-44.

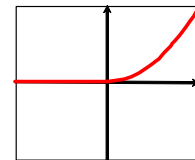
Linear Function - The Linear function returns a value directly proportional to the relationship, i.e., a positive satisfaction change will have a positive effect on friends and a negative effect on enemies in proportion to the strength of the relationship.



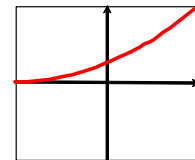
Quad Function - The Quad function is similar to the linear function, but is weaker when the relationships aren't as strong.



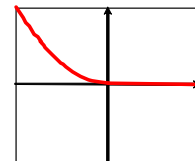
Friends Quad Function - The Friends Quad causes a satisfaction change to have an effect that is strong for strong friendships, weaker for very weak friendships and zero for enemies.



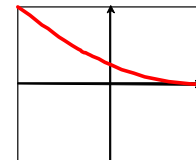
Friends More Function - The Friends More function is similar to the Friends Quad, except that a positive satisfaction change can still have a positive effect on enemies.



Enemies Quad Function - The Enemies Quad is similar to the Friends Quad, but reverses the effect for enemy relationships, i.e., a satisfaction change has a strong effect on enemies, a weaker effect on weak enemies and no effect on friends.



Enemies More Function - Enemies More is similar to the Friends More, but can have an effect on friends as well.



Force Presence and Activities are the things done by Force units which can affect civilian satisfaction. They are broken down into three categories: *force presence*, *combat*, and *force abstract activities*. Force presence “is the total number of personnel in units that belong to

the group and our present in the neighborhood.⁶⁷ Combat measures the number of personnel in units that are in combat in the neighborhood. Force abstract activities are activities that units can perform in a neighborhood. Some examples of activities include Law Enforcement, Curfew, Patrol, Provide Healthcare, etc... Some of these require a unit to be stationary (provide healthcare) while others can be conducted while moving (patrol, curfew). Most require some minimum level of security in order to be performed. For example, Healthcare requires a HIGH level of security, Law Enforcement a MEDIUM, and Patrol a LOW level of minimum security. (See table in Appendix III for the list of activities) As with other activities covered in the COOP model, there is a *coverage fraction* associated with the activities in JIN. This is intuitively logical, that the more troops that are performing a certain task relative to the size of the population, the more effective they will be in accomplishing the task and its effect on the population. This is carried a step further, such that when two groups are cooperating in a single activity (i.e., curfew) their efforts will be reflected in a *composite coverage fraction*.

Organization Activities are simply just the activities performed by organizations. Depending on the capability of the organization (engineer, support, or medical) they can perform activities such as Construction, Education, Healthcare, Infrastructure, etc... In all cases, the organization must be stationary in order to perform the activity.⁶⁸

Facilities Damage reflects situations where damage to a building causes some effect beyond the initial damage to just the building. Certain buildings such as power plants and hospitals provide services to a community or have significance to the community, such as mosques. JNEM maintains a database of facilities and their types in order to determine whether a

⁶⁷ Ibid., 44. As mentioned earlier, JNEM currently doesn't have the ability to differentiate between types of units, so it relies on sheer numbers. By convention, a unit that is in combat is unavailable to do anything else.

⁶⁸ Ibid., 48. Additionally, the minimum level of security for IGOs and NGOs is HIGH, while for contractors it is MEDIUM regardless of the activity they are to perform.

minimum threshold of damage has occurred and what type of abstract situation will be spawned by that damage. For example, damage to a Power Station can cause a POWEROUT situation in that neighborhood. Damage to a Chemical Warfare Production Facility could spawn abstract situations such as DISEASE, BADWATER, or BADFOOD. JNEM is careful to ensure that just repairing a facility does not necessarily resolve the abstract situation. For example, just because a unit attempts to repair a chemical plant after damage causes an industrial spill doesn't imply that they automatically cleaned up the spill.

The Distribution of Supplies was initially discussed in the COOP model, but there are a few points of expansion, regarding supply types, the consumption of supplies, and supply situations. The five types of supplies in JIN are: Construction, Food, Medical, POL, and Water. Each of them is used to mitigate certain abstract situations, such as DISEASE, BADFOOD, FOODSHRT, etc... The consumption of supplies is dependent on a couple of variables. The first is that the group receiving the supplies actually needs them to mitigate an abstract situation which is affecting them. Secondly, the security of the group in that neighborhood will affect how much they draw. Poor security equates to lower draw rates as people are afraid to come to the distribution point. Lastly, level of *stock* for a particular supply is always subject to a certain amount of *shrinkage*, which reflects theft, pilfering, vandalism, etc... dependent on the amount of security in the neighborhood. A *supply situation* is any time a group needs supplies in response to an abstract situation and there are supplies available from some Donor and Distributing group. The supply situation creates vectors. The vector is in turn passed to one of supply situation rule sets in JIN. There are five such rule sets, one for each supply type. The rule then assesses the satisfaction implications. The vector is also passed to JRAM's COOP model, which assesses the cooperation implications. Once a supply situation is started, it will continue to affect satisfaction and cooperation levels so long as the supply recipient is still drawing supplies. The important aspect here is that if a group can't draw supplies (due to poor

security) or the supplies are totally consumed, then the good will and cooperation garnered from the distribution will cease.

Security Checkpoints (SCP) model the effects of setting up checkpoints in the simulation which affect the flow of traffic. Each SCP has several characteristics: Location and Neighborhood; Force Group; Active vs Inactive; Permanent vs Temporary; Total Personnel; and Level of Intrusiveness. Every SCP has a physical Location and resides in a Neighborhood. Force Group is the group manning and operating the checkpoint. A SCP can be active or inactive. An inactive checkpoint has no affect on satisfaction or cooperation. While different aspects of the Federation allow for modeling vehicular, pedestrian and marine checkpoints, JNEM only models the vehicular checkpoints and ignores the rest. Permanent checkpoints are those that have a permanent structure, such as a border crossing, while temporary checkpoints do not, such as drunk-driving checkpoint. The important aspect is that permanent checkpoints have less of an effect on the population than temporary ones. The population is presumed to avoid or tolerate permanent checkpoints as their locations are known. Hence, they affect cooperation and satisfaction less than temporary checkpoints. However, even temporary checkpoints have a decreasing effect over time. Eventually, they have the same effects as permanent checkpoints. Total Personnel refers to the number of a force group manning the SCP. JNEM presumes that the number of personnel in a SCP is associated with the amount of traffic going through the checkpoint. Thus a greater number of personnel will have a greater affect on the population than smaller numbers of personnel. The *Level of Intrusiveness* is a range from LIGHT, MEDIUM, or HEAVY and corresponds to just waving vehicles through to full vehicle inspections. The intrusiveness of inspections also corresponds to the level of effect on satisfaction, the more intrusive the checkpoint, the greater the effect on the population.

JOUT

The following is a more detailed discussion of JOUT and how it performs Managing the Hostile Percentage, Rate Based Reactive Events, Organization Group Activity, and the JOUT Rule Sets.

In determining the Hostile Percentage, JOUT works with two primary variables, the desired and the actual hostile percentages. Recall that for each civilian group, there are civilian units which represent that civilian group's ability to take action inside of JNEM. Civilian units can be *non-hostile*, *supporter*, or *combatant*. At each major time step, or tock, JOUT computes the percentages for civilian units to change from non-hostile to hostile or vice versa. The *actual hostile percentage* is the total personnel in a particular group's hostile units divided by the total personnel in that group's potentially hostile units. The desired hostile percentage is somewhat more complicated:

The desired hostile percentage...is simply the actual hostile percentage we would like to have given (a group's) satisfaction levels and other factors. First, the base hostile percentage... is computed as a function of the group's playbox-wide mood by means of a Z-curve function... Next, a rule set is applied to adjust the base percentage, producing the adjusted hostile percentage... Finally, the adjusted percentage is multiplied by a volume control to produce the desired hostile percentage... The volume control is an arbitrary non-negative number, nominally 1.0, which may be set by the JNEM tech controller. The volume control thus allows EXCON to adjust the desired percentage up or down while still allowing it to vary with the group's mood.⁶⁹

When a non-hostile unit is selected to become hostile, it can become a supporter or a combatant. A combatant unit is one that is prepared to take violent action, which can be a JOUT generated mission or one that is explicitly assigned by EXCON. A supporter unit is one that provides material support to combatant units, though JNEM doesn't model these actions explicitly. Instead, JOUT maintains a ratio between combatant and supporter units. Based on

⁶⁹ Ibid., 63

subject matter expert input, that ratio is set at 8:1, or eight supporters for every combatant. “When it is time to make a unit hostile, JOUT determines whether or not there are more than enough supporters for the existing combatants. If there are, the new hostile will be a combatant; otherwise it will be a supporter.”⁷⁰

Rate-Based Reactive events are events generated by JOUT that affect population satisfaction or cooperation. There are *Short-Circuit* reactive events, which are events that are direct inputs back to JIN. However, most reactive events are targeted towards the rest of the Federation and influence the simulation or training audience in some way. Since the events are generated using a rate-based method, they are generated probabilistically using a Poisson process given a rate of events/day. Certain reactive events are targeted towards particular force groups; others are targeted towards all force groups. The table shows the events types, their targets and if they are explicit. Explicit events are ones where the event has a different rate for each civilian group in targeting a specific force group, such as the AGGROE event. By contrast, implicit events are events where each neighborhood group has a simple rate of events per day. Similar to the hostile percentage, reactive events are generated using a *base rate*, *adjusted rate*, and *volume control*, to produce the *effective rate*. Base rate is determined by a Z-curve based on the population group’s mood. Adjusted rate is derived from any rule sets in JOUT that adjust the base rate. Volume control is again an arbitrary number applied by EXCON to adjust the rate up or down.

⁷⁰ Ibid., 64. The same logic is used when deciding to change hostile units to non-hostile. JOUT will disable supporters units first unless the ratio forces it to disable a combatant due to the numbers falling below the minimum threshold. In determining which units to select for hostility, JOUT randomly chooses a neighborhood, and then randomly chooses a unit among the potential units in that neighborhood and makes it hostile. However, JOUT also uses an algorithm designed to favor choosing potential hostile units from the neighborhoods with the worst problems. This makes intuitive sense, as a completely random distribution of hostile units wouldn’t reflect the reality of differences between neighborhoods.

Table 1. Rate based reactive events.

Once an event has been selected, it must still be executed. JOUT first *schedules* the event, then executes it either immediately or puts it on the *pending events list* to be executed later, depending on the nature of the event.

The footnote below has a short synopsis of each type of reactive event from the adjacent table.⁷¹ CARDIS and CARSAT are Civilian Activity reports.

EVENT TYPE	TARGETS	EXPLICIT?
AGGROE	Coalition force groups	Yes
ASSASS	Other civilian groups	No
CARDIS	All force groups	Yes
CARSAT	All force groups	Yes
CIVINF	All force groups	Yes
EXPHOS	Coalition force groups	Yes
HIJACK	Other civilian groups	No
KIDNAP	Other civilian groups	No
OARDIS	All force groups	No
OARSAT	All force groups	No
SUBOMB	Other civilian groups	No

A civilian activity report (CAR) indicates that members of civilian group... have performed some activity which indicates either general satisfaction (CARSAT) or general dissatisfaction (CARDIS). This report is sent to the federation, where it is converted by one means or another into a message to the training audience; by considering these reports in the aggregate, the training audience should be able to determine the mood of each neighborhood of interest. CARs are always executed immediately.⁷²

⁷¹ Ibid., 70. AGGROE or Aggressive ROE is the only example of an explicit hostile mission. AGGROE causes a civilian combatant unit to go into combat against a particular coalition force group in the ground simulation. The abstract hostile missions are: ASSASS (Assassination of local civilian), HIJACK (Hijacking of local civilian vehicle), KIDNAP (Kidnapping a local civilian), and SUBOMB (Terror bombing in a neighborhood). The abstract hostile missions are considered implicit, as they occur in JNEM, but not in the ground simulation. In other words, a coalition patrol will not 'see' or witness a hijacking, though it will be reported. The implicit hostile mission stays within JNEM and becomes a JIN input which in turn affects civilian satisfaction levels

⁷² William H. Duquette, *JNEM 3.0.14 JIN Rules*, (California, 2008), 70. A note of interest is the way CARs are targeted towards a particular force group. The presence of units from a force group and their activities can increase the rate at which CARs are sent to that force group

In practice, the ISM station sends messages to the training audience based upon the calculated ‘mood’ of a particular group. The actual mood number falls into one of several categories (Very dissatisfied, somewhat dissatisfied, neutral, etc..) Depending on the category, the ISM sends out preset messages. I.e. – there are 15 to 20 messages associated with a particular group having a dis-satisfied mood. There are 15-20 more messages associated with the neutral mood, etc...The importance of this is that the training audience never sees the mood number or associated category generated by JNEM. It is up to them to interpret the message in order to correctly judge the mood, which is the same as the everyday occurrence of attempting to judge the mood of people by their behavior.⁷³ This raises the question of whether a training audience should be allowed to conduct ‘polling’ of groups, which is currently not allowed. Rather than trying to rely on interpreting outward behavior, the training audience can ‘ask’ the groups and get a better pulse for the mood.

Organization activity reports (OAR) are the equivalent of CARs, but for Organizations. OARDIS and OARSAT correspond to a general dissatisfaction or satisfaction of an organization group. CIVINF or Civilian Information reports are like the tips that come from citizens to a police hotline. They indicate that some sort of actionable intelligence went to the training audience (other than the location of a hostile civilian unit). The last type of reactive event is EXPHOS or Expose Hostile Unit. In this event, “JNEM notifies the federation of the present whereabouts of a hostile civilian unit – a combatant or a supporter – with the intent that the training audience will be notified of the unit’s presence and location in some appropriate way. EXPHOS event are always executed immediately.”⁷⁴

⁷³ Jack Goodman, *Interview*, ed. Ripley, Royal S. MAJ (Fort Leavenworth, KS:, 18 July 2008)

⁷⁴ Duquette and Chamberlain, *JNEM Analyst's Guide*, 72. Currently, the selection of which hostile unit to expose is done randomly for all hostile units in the playbox. The JNEM Analyst’s Guide acknowledges that a better selection model is needed.

The Organization Group Activity tells JOUT whether an organization group is *active* or *inactive*, whether that is in a particular neighborhood or playbox wide. An inactive group means the group's personnel are unwilling to work in the relevant neighborhood. If a group is inactive, then it will have no effect on population satisfaction levels, regardless of any assigned activities or security level.

The JOUT Rule Sets are three sets of rules governing the adjustment of rates or activity. The HOSTILE rule set adjusts the base hostile percentage. The Rate Rule sets adjust the base rate of occurrence of reactive events. The ORGACT rule set determines whether organization groups are active or inactive, whether playbox wide or in particular neighborhoods.

JNEM Analysis and Diagnostic tools

The last part of the description of JNEM is a synopsis of the Analysis and Diagnostic tools available to help interpret data. If not already apparent, the inner workings of JNEM are abstract and difficult to disentangle in order to determine causality for behaviors in the model. Some commonly asked questions include, "What caused the spike in so-and-so's AUT satisfaction just then? What were the general effects of BLUE's actions during the exercise? How important were BLUE's actions relative to everything else going on? What events and situations had the strongest impact in this particular neighborhood?"⁷⁵ These types of questions can be exceedingly difficult to answer due to the immense complexity of the model. Direct effects, indirect effects, indirect effects from other neighborhoods all make contributions to changes in satisfaction levels.

JIN rule firings, though important, are a red herring. All inputs to NSAT are in fact caused by monitored and abstract events and situations. An analyst isn't primarily concerned with the effect of a particular rule firing, but with the effect of a particular event or situation. And when he asks, 'What caused this satisfaction curve to spike at this time?' he wants to know which events or

⁷⁵ Ibid., 74.

situations were responsible. Moreover, he's often going to be more interested in what happened thirty minutes, or an hour, or three days ago than he is in what's happening right now, this minute.⁷⁶

The real issue is finding which events and situations contributed to a particular satisfaction curve during a particular time window.

We answer this question as follows. First, JIN keeps records of every event and situation that affects satisfaction. Next, each input to NSAT is tagged with the identifier *e* of the event or situation that produced it. Finally, at each time advance *t*, NSAT keeps track of the actual contribution (of each event to the satisfaction curve). This historical data is saved in a table and made available to the rest of the simulation...In practice, this value is computed for all events that made non-zero contribution to the curve during the time window, and the results are rank ordered by the absolute size of the contribution. The analyst can then see at a glance which events were the most significant, and precisely what effect they had.⁷⁷

Using this historical database as a tool, JNEM allows analysts to get at answering some of the commonly asked questions posed above. Additionally, JNEM can also compute a projected importance, which is “an estimate of the importance-to-date of the event or situation as of the end of the exercise.”⁷⁸

⁷⁶ Ibid., 74.

⁷⁷ Ibid., 74-75.

⁷⁸ Ibid., 77.

Analysis

In analyzing the JNEM model for a potential ability to conduct forecasting, several critiques become evident: its use as a training aid, the use of implicit versus explicit assumptions regarding causation, the use of arbitrary values, the use (or lack thereof) of feedback to refine equations, and the concept of emergence.

The current usage of JNEM is directed towards conducting quality training events. According to Mark DeMike, Deputy Chief for the PMESII Division, JNEM is being used in two different styles of training exercises. The first is, Mission Rehearsal Exercises (MRX) which serves as a certification for Corps and Division Headquarters to function as Joint Task Force (JTF) headquarters prior to deployment into Iraq or Afghanistan. MRXs are heavily scripted events that utilize MSELs in order to achieve specific training objectives. By design, MRX's are heavily constrained, intended to ensure the target unit passes through designated training gates. The other style is the Warfighter exercise which allows more free play in the scenario.⁷⁹

However, even the Warfighter exercises are subject to a certain amount of criticism as they too are driven by training objectives. According to Ben Jordan at TRISA, "JNEM was built to optimize for free play, but in reality it is not used in a way that maximizes the way it was designed."⁸⁰ This is not a pejorative, but simply reflects the manner in which we train or 'certify' Corps and Division Cdr's and Staff. The basic critique is that the MSEL play for an MRX trumps the free play that would develop if the system were left to itself. In a true free play environment, there is no telling what situations would develop as the training audience interacts with the

⁷⁹ DeMike, *Interview*

⁸⁰ Jordan, *Interview*

system. However, in an MRX environment the training audience unit is required to demonstrate competency in certain tasks and criteria. Hence, the MRX cannot be left to ‘chance’ by the free play, but uses MSELs to ensure that particular problem sets are introduced into the scenario. This is good for training, but can leave an observer wondering how realistic the simulation is when things are going great for the first ten days and then suddenly major riots appear to burst forth from out of nowhere. In its optimized state, JNEM is designed to reflect a ‘thinking OPFOR’, competing BLUEFOR (as in competing with each other, not just against the OPFOR), and multiple competing sides.⁸¹

In order to examine the critique of the Implicit vs Explicit assumptions, we will need to quickly understand the concept of ‘folk psychology’ as laid out by Alexander Rosenberg in his ‘*Philosophy of Social Science*’. Rosenberg discusses the philosophical nature of social science and the differences between natural and social sciences in the nature of knowledge, derivation of hypotheses, and methods to determine ‘causation’.

Unlike the natural sciences, which aim at causal theories that enable us to predict and control, the social sciences seek to explain behavior by rendering it meaningful or intelligible. They uncover its meaning, or significance, by interpreting what people do. The interpretation of human behavior, in this view, is not fundamentally causal. ...Though understanding the meaning of actions is not directed at merely uncovering causes, it certainly satisfies some standards of predictive success: The correct interpretation of human actions enables us to navigate successfully in a society of other human beings....,we can not fail to be impressed with the implicit theory that growing up in society has provided us. This theory, known as ‘common sense’ or ‘folk psychology,’ tells us obvious things we all know about ourselves and others. For instance, people do things they do roughly because they want certain ends and believe the acts will help attain them.⁸²

⁸¹ Ibid.

⁸² Alexander Rosenberg, *Philosophy of Social Science*, 3rd ed. (Boulder, CO: Westview Press, 2008), 21.

Thus folk psychology is really just the ‘common sense’ that we apply to our everyday lives, and for the most part, it works pretty well. It includes such commonplace observations as, hot sunny days cause sunburns which will hurt, thirst causes drinking, or men will gawk at pretty girls. Yet, while these may seem ‘common sense’ they are also subject to many exceptions, such that the list of qualifiers for every exception would quickly grow exhaustive. One might conclude that thirst does not in fact cause drinking; however as a generalization we accept that it is true. “Whether it is a scientific theory or not, folk psychology is still the best theory we have for predicting the behavior of people around us, and it’s the one we employ when we explain our own and other’s behavior...Folk psychology enables us to predict by identifying the meaning of behavior – by showing that it is action undertaken in the light of beliefs and desires.”⁸³ However, there are limits to what folk psychology can tell us, especially about other cultures. The common sense observation of ‘men will gawk at pretty girls’ might make sense in some cultures, but make absolutely no sense in others. However, this does not preclude our ability to learn about other cultures such that we can make predictions about them. “Indeed, we can acquire as much predictive confidence about them as our own folk psychology provides us about ourselves. For what we are learning is in effect their folk psychology.”⁸⁴

In the case of Implicit vs Explicit assumptions, JNEM-in-theory and JNEM in-practice is vague about where certain assumptions originate. Several times, the authors cite the phrase ‘that subject matter experts’ were consulted in determining the initial values for some parameter, or the values that should be used for a parameter that modifies an equation. The nature of those consultations should be transparent, along with citing the various studies that were utilized in order to generate baseline numbers for things such as a particular group’s Autonomy or Safety. Ben Jordan at TRISA was particularly helpful in ‘peeling the onion’ on how data is quantified.

⁸³ Ibid., 22.

The quantification is SME-defined, which raises the question of who are the SMEs? The SME's in this case are the various analysts of TRISA's Threat Directorate. They rely primarily on secondary research and are capable of producing classified reports though none have been requested to date in order to support an exercise. This in turn raised the question of whether the SME's take a comparative politics approach to generating the data. Mr. Jordan's response was a telling, "No."⁸⁵

The real difficulty is trying to describe a 'behavior' or a view of autonomy as being associated with a 'cause' and subsequently being assigned a discrete number that JNEM can utilize. For example, in *The Logic of Violence in Civil War*, Stathis N. Kalyvas points out the differences between violence as an outcome and violence as a process. Because of these distinctions, it becomes exceedingly difficult to observe a certain behavior (or expressive motivation) and determine the causes. "In general, it is extremely difficult to uncover with an acceptable level of accuracy the individual motives behind violent acts. Deducing motive from behavior is a bad idea, as is replacing evidence with politically motivated classifications, as in the case of 'hate crime': the problem of observational equivalence is common since a particular act may be consistent with several motives."⁸⁶

In all fairness, the Analyst's Guide is a general theoretical description of how the model functions, and arguably wouldn't include specifics for how parameters were generated. Additionally, as Ben Jordan correctly points out, "Eventually some individual has to make a judgment call as to what the numbers should be."⁸⁷ However, this highlights the fact that the presumptions used should be specific, explicit and transparent. The model is currently used to

⁸⁴ Ibid., 23.

⁸⁵ Jordan, *Interview*

⁸⁶ Stathis N. Kalyvas, *The Logic of Violence in Civil War* (Cambridge: Cambridge University Press, 2006), 24.

simulate Iraq, Afghanistan, Korea and a notional exercise situated in the Caucasus, but there is risk in thinking that an Iraq specific version of JNEM would have the same parameters (or variables) as a version intended for another country or situation. A different playbox would have different parameters, but without being explicit with regard to how those parameters were obtained, then the JNEM model just continues to repeat the ‘folk psychology’ error outlined earlier.

Related to critique of implicit assumptions, is the use of arbitrary values on the part of JNEM designers. There is an irony in this critique as JNEM was created in part to overcome the arbitrary nature of previous training simulations and exercises. In the past, it was a common complaint by exercise participants about the arbitrary way that Observer-Controllers (OCs) would adjudicate what was going on in simulation (especially if the OC had no experience or antiquated experience with the region or situation in play). It was sometimes referred to as the ‘OC Bias Factor.’⁸⁸ In the current context, the critique goes to the question of how to determine whether arbitrary values (such as the initial settings for Safety, Autonomy, Quality of Life, and Culture) are accurate. As JNEM uses a sliding scale (-100.0 to 100.0) then the question of accuracy becomes ‘accurate relative to what?’ JNEM implementers apparently came up with a very practical and useful answer that groups are relative to each other. For example, the Shia group in this neighborhood is much happier about this concern than the Kurdish group. As with the implicit vs. explicit assumptions, this works and suffices to get the model working, but doesn’t necessarily reflect an accurate truth. This is where the discipline of comparative social sciences comes in. As Todd Landman points out in *Issues and Methods in Comparative Politics*:

Scholars compare to provide context, make classifications, test hypotheses, and make predictions. They do this by comparing many countries, few countries, or they provide in-depth studies of single countries. As there are

⁸⁷ Jordan, *Interview*

⁸⁸ DeMike, *Interview*

many trade-offs associated with these different goals and methods of comparison, there are also important fundamental problems, which if not addressed explicitly can limit the types of generalizations that can be drawn from any study.⁸⁹

These problems include: too many variables and too few countries, establishing equivalence, selection bias, spuriousness, ecological and individualist fallacies, and value bias. Focusing on just the problems of establishing equivalence (is the comparison meaningful), spuriousness (mistaking an unidentified factor as being attributed to an effect), and value bias (the problem of perspective in seeing the world); JNEM can be confusing in how it determines causes when they are attributed to particular events.⁹⁰ Kalyvas echoes the same dangers but using different biases, when he cites social scientists as being guilty of partisan bias, political bias, urban bias, selection bias, and over-aggregation bias.⁹¹ So, even if JNEM uses ‘good’ data, that data should be subject to a certain amount of circumspection. A good historical example can be drawn from the Vietnam War where Secretary of Defense McNamara tried to use computer simulations to determine how much progress was being made in various programs. “...McNamara put more than a hundred sociologists, ethnologists, and psychologists to work ‘modeling’ South Vietnamese society and seeking data sufficient ‘to describe it quantitatively and simulate its behavior on a computer.’ Of course, the project was based on circular reasoning – how could anyone judge which data were relevant unless one already had a model in mind?”⁹²

A related critique of JNEM is the effect of the larger political structure on the sense of Autonomy for different groups. As JNEM was originally built around an Iraq scenario, this seems to be implied. However, the difference between political structures (especially one that is trying

⁸⁹ Todd Landman, *Issues and Methods in Comparative Politics : An Introduction*, 2d ed. (London ; New York: Routledge, 2003), 40.

⁹⁰ Duquette and Chamberlain, *JNEM Analyst's Guide*, 18.

⁹¹ Kalyvas, *The Logic of Violence in Civil War*, 32-51.

⁹² Walter A. McDougall, *Promised Land, Crusader State: The American Encounter with the World since 1776* (New York, NY: Houghton Mifflin Company, 1997), 189.

to move towards a democracy and democratic principles) makes a large difference in how different groups act. Marina Ottaway in her book – *Democracy Challenged: The Rise of Semi-Authoritarianism*, lays out an argument that semi-authoritarian regimes, ones that purposefully have the outward appearance of democracy, but in fact remain under strong man rule have become more numerous in the last decade of the 20th century. “They are ambiguous systems that combine rhetorical acceptance of liberal democracy, the existence of some formal democratic institutions, and respect for a limited sphere of civil and political liberties with essentially illiberal or even authoritarian traits.”⁹³ The point of this is that there are fundamental differences in the way different groups are treated in different types of societies. Using Ottaway’s model of Authoritarian, Semi-Authoritarian, and Democratic regimes, there should be explicit parameters for the way different ethnic/religious groups are treated and their corresponding sense of Autonomy. Currently, JNEM groups Coalition forces together under one umbrella (Blue). Those Coalition forces include forces of the prevailing government, though it does differentiate between US Army, Host nation conventional forces, and police. As noted above, these blue force groups are presumed to be cooperative with each other, while in reality they can also be competitors. In certain situations this is probably appropriate, but it does highlight the fact that not all supposedly democratic countries are in fact ‘democratic’. “Semi-Authoritarian regimes are hybrids. They allow little real competition for power, thus reducing government accountability. However, they leave enough political space for political parties and organizations of civil society to form, for an independent press to function to some extent, and for some political debate to take place.”⁹⁴ Ottaway concludes “But the superficial stability of many semi-authoritarian regimes usually mask

⁹³ Marina Ottaway, *Democracy Challenged : The Rise of Semi-Authoritarianism* (Washington, D.C.: Carnegie Endowment for International Peace, 2003), 3.

⁹⁴ Ibid., 3.

a host of severe problems and unsatisfied demands.”⁹⁵ As well that “... an analysis of the workings of semi-authoritarian regimes shows that all sorts of conditions – for example, stagnant economies or ethnic polarization – matter, and matter a great deal at that.”⁹⁶ The point of this critique is that the assumptions regarding the overall political system and its corresponding effect on any one playbox should be made explicit.

This is echoed by Misagh Parsa in *States, Ideologies, & Social Revolutions*, where the larger structure of the state and its policies has a bearing in the level of violence encountered or caused by the population. Parsa lays out an argument that the policies a government pursues can increase or decrease support for the state. “In the end, state intervention and state development strategies increased social inequalities and narrowed the social basis of support for the state.”⁹⁷ While Parsa doesn’t develop a nuanced view of democracy the same as Ottaway, he does conclude that democratic processes and economic development do affect the challenges posed to a state.

The development of formal democratic institutions, which expand the polity and permit moderate political organizations access to the state, tend to reduce the likelihood of large-scale political conflicts. ... Similarly, to the extent that governments become less hyperactive, less interventionist and allow market forces to determine capital allocation and accumulation, the state will be insulated from the type of challenges studied in this research.⁹⁸

However, before a JNEM training audience should draw the link between a peaceful playbox and the development of a free market, they should understand that the link isn’t always

⁹⁵ Ibid., 5.

⁹⁶ Ibid., 13.

⁹⁷ Misagh Parsa, *States, Ideologies, and Social Revolutions: A Comparative Analysis of Iran, Nicaragua, and the Philippines* (Cambridge, UK ; New York: Cambridge University Press, 2000), 55.

⁹⁸ Ibid., 294.

clear, “Furthermore, the expansion of free markets may continue to exacerbate class conflict and ethnic divisions and provide ample cause for conflict.”⁹⁹

In considering JNEM from the aspect of emergence, the central idea behind the critique is that JNEM has a limited (at best) ability to show ‘emergence’ as an aspect of populations. From the discussion on Complexity and CAS, emergence is a coherent behavior (or a pattern) that is generated by a large population of agents intensely interacting with each other. From the JNEM-in-practice interviews, it becomes clear that JNEM can’t really reproduce this phenomenon. “If the exercise director wanted to describe an ‘emergent property’, we could ‘magically’ set the neighborhoods surrounding the target neighborhood to ‘here’ and dial up the effect.”¹⁰⁰ Essentially, this could ‘replicate’ an emergent property or the concept of overlapping identities without explicitly defining those things in the rule sets. Interestingly enough, the concept of folk psychology identified earlier is dependent on recognizing patterns. “The success of folk-psychological prediction, like the success of any prediction, depends on there being some order or pattern in the world to exploit.”¹⁰¹

In effect, the play boxes and their individual population groups have become the ‘agents’ of the JNEM model. The question was asked if the proximity matrix for a particular event could be changed, such that adjacent neighborhoods would have the same effect as HERE, thus changing the nature of the relationships. While the proximity matrix can be changed, it is really only a facsimile of emergence. Emergence can be replicated by rule based systems but those models are built around an agent-based architecture vice the rule based architecture of JNEM.¹⁰² Some might think this is an unfair criticism of JNEM, but in modeling CAS based systems the

⁹⁹ Ibid., 295.

¹⁰⁰ Atwood, *Interview*

¹⁰¹ Daniel C. Dennett, "Real Patterns," *The Journal of Philosophy* Volume 88, no. 1 (1991): 30.

¹⁰² Holland, *Emergence: From Chaos to Order*, 122-3.

concept of emergence is an important component of CAS. One possible solution would be to increase the number of allowable ways to draw and overlap neighborhoods. This would create numerous ‘pseudo-agents’. The idea has several positive aspects: it would allow population groups to project different identities based upon the multiple, overlapping neighborhoods. For instance, there are many examples in the real world where tribal groupings exist irrespective of national boundaries, such as the Kurds whose ethnic boundaries extend into Turkey, Iraq and Iran. Rather than trying to split Kurds up along national boundaries, the idea of multiple neighborhoods would allow the Kurds to reflect more than one sense of identity in a playbox. Even though JNEM puts no limits on the number of population groups or the number of neighborhoods, (conceivably every family unit could be its own neighborhood) it raises the problem that once the box is drawn, it can’t be re-drawn in accordance with the different ways that people identify themselves or with others. For instance there are several equally valid methods of drawing neighborhood boxes, either by political boundaries (provinces/suburbs), or by ethnic boundaries (ethnic/tribal/sub-tribal structures) or by economic boundaries (wealth/social class/urban & rural distinctions). This critique is not novel, as Ben Jordan points out “the utility of different neighborhood boxes would be very useful, especially from the standpoint of using multiple boxes and making multiple runs, in order to compare the results.”¹⁰³ The example was used of drawing the boxes based upon political boundaries and then comparing the results if the boxes were drawn based upon economic or religious boundaries. Mr. Jordan sees a great utility for experimentation in these cases. These multiple boxes could be useful for reflecting different identities within population groups. This sort of thinking is also echoed by Holland “Still, by executing the computer-based model several times, with different initial

¹⁰³ Jordan, *Interview*

settings, we may discern patterns and regularities that recur in the results.”¹⁰⁴ Potentially this approach could also address the problems identified with different bias on the part of the SME’s that determine initial values and boxes.

Considering JNEM from the aspect of feedback, the critique is simply that there is none. Recall the importance of this in building a model of CAS systems, the model should also be able to change or exhibit a degree of learning. JNEM keeps ‘score’ for concerns, but is there is no method for modifying the rules in game time to reflect ‘learning’ on the part of the population, or to modify the weighting of rule sets in order to provide a better forecast of the mood of the population. “JNEM does the same thing over and over again.”¹⁰⁵ In all fairness, most JNEM simulations are focused on two week exercises, so the opportunity to demonstrate ‘learning’ for example by a change in saliency never really has a chance to occur. “Most JNEM training events run for only a week or two, and are conducted in ‘real time’, that is the time ratio between real time and exercise time is 1:1. Thus, BCTP has never run a JNEM simulation long enough where a change in saliency would become a factor.”¹⁰⁶ “Saliency is set at the beginning of database definition but is not dial-able (it can’t be changed).” This precludes a change in saliency over time, such that as a security situation improves over the course of a year or more, it would become of less and less importance to a group as a central concern.¹⁰⁷

¹⁰⁴ Holland, *Emergence: From Chaos to Order*, 120.

¹⁰⁵ Goodman, *Interview*

¹⁰⁶ Pember, *Interview*

¹⁰⁷ Atwood, *Interview*; Goodman, *Interview*

Conclusions and Areas for further study

Conclusions

In conclusion, JNEM isn't suited to serve as a tool for correlated analysis and forecasting. As acknowledged earlier, it was never designed with that intention in mind. In response to the direct question 'Could the JNEM model be used for forecasting?' Tim Metivier, Director of the Constructive Simulations Division, NSC responded "In short, no. JNEM was not designed with that purpose in mind. What you are suggesting would be a very different model with a very different structure."¹⁰⁸ Even though JNEM wasn't designed with this in mind, it doesn't lessen the relevance of examining its potential for different uses. History is replete with examples of objects which were created for one purpose but found greater utility or even fame when utilized in a completely different method.¹⁰⁹ Additionally, the context of the original premise (could JNEM be utilized as a forecasting tool?) remains unchanged. It would be incredibly useful for a commander to have access to such a tool while preparing for an operation or while engaged in some sort of irregular warfare. In the end, the essence of the problem boils down to the issue of how to quantify the qualitative. JNEM represents a very good start towards building such a tool, but it isn't developed enough for use in the envisioned alternate role.

With regard to the question of whether it is possible in theory to build such a tool, the answer is a qualified yes. We perform exercises in prediction of large scale human behavior all the time. Using a computer simulation in order to aid in those predictions is quite natural, with several different methods and tools available. In his book *Super Crunchers*, Ian Ayres points out that certain methods of statistical analysis (the Super Crunching) are superior to reliance on

¹⁰⁸ Tim Metivier, *Interview*, ed. Ripley, Royal S. MAJ (Fort Leavenworth, KS.; 18 July 2008)

¹⁰⁹ The WWII fighter aircraft (P-51D Mustang) is an example of an item designed for one purpose (short range defensive fighter) that found fame when utilized in a different role (long-range escort fighter).

human intuition (though there are always exceptions). This is due to human cognitive failings and biases which result in poor predictions (bias and overconfidence) and that Super Crunchers make better predictions by doing a better job at figuring the weights to put on individual factors, and not being overconfident or emotional about it. Ayres even asserts that Super Crunchers can determine the quality of the prediction.¹¹⁰ This use of statistical analysis (regression and randomized trials) using large sets of data can give interesting insights into human behavior and potentially translate into better predictions than over-reliance on SME's. "The regression literally produces an equation that best fits the data. Even though the regression equation is estimated using historical data, the equation can be used to predict what will happen in the future."¹¹¹ This is not the only example, where a machine based algorithm can demonstrate proficiency at outperforming human qualitative assessments. In 2007, teams of Human intelligence analysts were pitted against a computer algorithm in a test to identify the command and control (C2) structure for a notional enemy insurgent network. The teams were normalized for experience levels and subjected to various noise levels and C2 architectures in the data.

Briefly, the findings show that the unaided human can perform organization identification at level far better than chance however the NetSTAR system is 100% better than the humans at this task. When the humans attempt to describe and map attributes of the identified organization they fared poorly, however the NetSTAR system showed little diminution in performance even under noise level (amount of error present) that severely decreased human's performance.¹¹²

The other question is whether it is feasible? The answer for that question in relation to JNEM is no. JNEM's basic structure, while fundamentally sound, doesn't include some of the

¹¹⁰ Ian Ayres, *Super Crunchers* (New York, NY: Bantam Dell, 2007), 114-115.

¹¹¹ *Ibid.*, 24.

¹¹² Elliot E. Entin et al., *Identifying the Enemy - Part II: Algorithms Versus Human Analysts*, (paper presented at the Command and Control Research and Technology Symposium, New Port, RI., June 19, 2007), 1.

components necessary for it to provide ‘forecasts’ of any reliability. Its basic structure has several interesting components and does reflect a certain level of realism, however, it does not possess a capability to demonstrate emergence or to ‘learn’ from its environment through feedback. The use of implicit and explicit assumptions along with arbitrary values also limits JNEM’s potential ability to ‘forecast’ though they don’t necessarily preclude it.

Areas for further study

While JNEM is clearly not suited as a forecasting tool as envisioned in the research hypothesis, there is another simulation built on the same premise as JNEM but could be suited as just such a tool. The simulation is named ‘Minerva’ and is currently in development. As conceptualized, Minerva would be more of an analysis tool vice a training tool. It would take the current functionality of JNEM and add additional models, to include economic systems (examining supply and demand), political systems (style of government), demographic systems (age/population), Information effects, and ‘clout’ for various actors. The goal would be to substantially improve the quantitative study of Irregular Warfare situations, though the model would still be subject to the same issues of emergence and feedback identified earlier. Examining the Minerva model and other related efforts would assist in advancing the art of simulation and could contribute to useful tools for campaign designers and planners.

In addition to Minerva, which is still a rule based simulation, other agent-based simulations are another area of inquiry. Agent-based simulations treat each individual person (or small group) as an independent agent, capable of making simple decisions based upon locally available information. These types of simulations are noted for producing interesting results (as well as demonstrating emergent behavior) but are very computationally intensive, which can limit the size of the simulation or the types of architectures available to run them.

Appendices

Appendix I – Glossary of Terms, Acronyms

BCTP	Battle Command Training Program
CAR	Civilian Activity Report
CAS	Complex Adaptive Systems
CBS	Corps Battle Simulator
CIVSAT	Civilian Satisfaction Report
COOP	Cooperation Model
CTR	Contractor
EXCON	Exercise Control
HLA/RTI	High-Level Architecture/Run-Time Infrastructure
IGO	Inter-Governmental or International Organization
ISM	Independent Stimulation Module
JIN	JNEM Input Module
JLCCTC	Joint Land Component Constructive Training Capability
JNEM	Joint Non-kinetic Effects Model
JOUT	JNEM Output Module
JRAM	JNEM Regional Analysis Model
JTF	Joint Task Force
MRF	Multi-Resolution Federation
MRX	Mission Rehearsal Exercise
MSEL	Mission Scripted Event List
NGO	Non-Governmental Organization
NSC	National Simulation Center

OAR	Organization Activity Report
O/C	Observer/Controller
OPFOR	Opposing Force
ORGSAT	Organization Satisfaction Report
PMESII	Political, Military, Economic, Social, Information, Infrastructure
RMF	Relationship Multiplier Function
SCP	Security Checkpoint
SIC	Sensitivity to Initial Conditions
SME	Subject Matter Expert
TRADOC	Training and Doctrine Command
TRISA	TRADOC Intelligence Support Activity
UN	United Nations
WARSIM	Warfighters' Simulation

Appendix II – JNEM symbols

MATH SYMBOL	TEXT SYMBOL	DEFINITION
A	A	ACTIVITY INDEX
C	C	CONCERN INDEX
E	E	REACTIVE EVENT INDEX
F	F	POPULATION GROUP INDEX; USED AS A PAIR WITH G.
G	G	POPULATION GROUP INDEX
K	CAUSE	THE “CAUSE” OF AN NSAT LEVEL OR SLOPE EFFECT.
M	M	NEIGHBORHOOD INDEX; USED AS A PAIR WITH N.
N	N	NEIGHBORHOOD INDEX
$acontrib_i(t_1)$	ACONTRIB	ACTUAL CONTRIBUTION-TO-DATE OF NSAT LEVEL OR SLOPE EFFECT <i>I</i> AT TIME STEP t_1 .
$Conflicts_n$		IN JIN, THE POTENTIAL NUMBER OF CONFLICTS BETWEEN FRIENDS AND ENEMIES IN NEIGHBORHOOD <i>N</i> .
$Coverage_{na}$	COVERAGE.NA	COMPOSITE COVERAGE FRACTION FOR ACTIVITY A IN NEIGHBORHOOD <i>N</i> .
$Coverage_{nga}$	COVERAGE.NGA	COVERAGE FRACTION FOR ACTIVITY A BY GROUP G IN NEIGHBORHOOD <i>N</i> .
$\delta_i(t_1, t_0)$		NOMINAL CONTRIBUTION TO SATISFACTION OF NSAT LEVEL EFFECT <i>I</i> AT TIME STEP t_1 .
$delay_{mn}$	EFFECTS_DELAY.MN	TIME DELAY IN DECIMAL DAYS FOR AN NSAT INPUT IN NEIGHBORHOOD <i>N</i> TO HAVE A INDIRECT EFFECT IN NEIGHBORHOOD <i>M</i> .
D_{ng}		IN JIN, DEMEANOR FORCE MULTIPLIER
ε		IN NSAT, AN “EPSILON” VALUE THAT AFFECTS LEVEL AND SLOPE EFFECTS.
$E(t)$		REALIZATION CURVE FOR AN NSAT LEVEL EFFECT.
E_{CIV}		IN JOUT, SET OF ALL CIVILIAN REACTIVE EVENTS
E_{ORG}		IN JOUT, SET OF ALL ORGANIZATION REACTIVE EVENTS
E_i		IN JIN, UNIT FORCE MULTIPLIER BASED ON UNIT AND GROUP TYPE.
E_{ng}	EFFECTS_FACTOR.NG	IN NSAT, THE <i>EFFECTS FACTOR</i> FOR NEIGHBORHOOD GROUP NG.

MATH SYMBOL	TEXT SYMBOL	DEFINITION
$Enemy_{ng}$		FORCE OF GROUP G 'S ENEMIES IN NEIGHBORHOOD N , INCLUDING ENEMIES IN NEARBY NEIGHBORHOODS.
$\%Enemy_{ng}$	ENEMY.NG	FORCE OF GROUP G 'S ENEMIES IN NEIGHBORHOOD N , INCLUDING ENEMIES IN NEARBY NEIGHBORHOODS, AS A PERCENTAGE OF TOTAL FORCE IN N .
$\phi_i(t_1, t_0)$		NOMINAL CONTRIBUTION TO SATISFACTION OF NSAT SLOPE EFFECT I AT TIME STEP t_1 .
far_{mn}		PREDICATE FOR $proximity_{mn}$ = "FAR".
F_i		IN JIN, FORCE MULTIPLIER FOR PERSONNEL IN UNIT I .
F_{ng}		IN JIN, FORCE MULTIPLIER FOR CIV GROUP G IN NEIGHBORHOOD N .
$Force_{ng}$		GROUP G 'S FORCE IN NEIGHBORHOOD N , INCLUDING FRIENDS IN N AND NEARBY NEIGHBORHOODS.
$\%Force_{ng}$	FORCE.NG	GROUP G 'S FORCE IN NEIGHBORHOOD N , INCLUDING FRIENDS IN N AND NEARBY NEIGHBORHOODS, AS A PERCENTAGE OF TOTAL FORCE IN N .
G_{ALL}		SET OF ALL POPULATION GROUPS
G_{CIV}		SET OF CIVILIAN GROUPS
G_{FRC}		SET OF FORCE GROUPS
G_{ORG}		SET OF ORGANIZATION GROUPS
H		IN JIN, FRACTION OF FORCE IN NEARBY NEIGHBORHOODS TO INCLUDE IN FORCE ANALYSIS.
h_g	HOSTILE.G	DESIRED HOSTILE PERCENTAGE FOR GROUP G .
ha_g	HOSTILEA.G	ADJUSTED HOSTILE PERCENTAGE FOR GROUP G .
hb_g	HOSTILEB.G	BASE HOSTILE PERCENTAGE FOR GROUP G .
h'_g		ACTUAL HOSTILE PERCENTAGE FOR GROUP G .
$here_{mn}$		PREDICATE FOR $proximity_{mn}$ = "HERE".
I_k^+, I_k^-		SET OF LEVEL OR SLOPE EFFECTS WITH CAUSE K AND A POSITIVE OR NEGATIVE MAGNITUDE, RESPECTIVELY.
L_{ngc}	SALIENCY.NGC	IN NSAT, THE IMPORTANCE (SALIENCY) OF CONCERN C TO GROUP G RESIDING IN NEIGHBORHOOD N .

MATH SYMBOL	TEXT SYMBOL	DEFINITION
$LocalFriends$		GROUP G 'S FORCE IN NEIGHBORHOOD N , INCLUDING FRIENDS IN THE NEIGHBORHOOD.
$LocalEnemies$		THE FORCE OF GROUP G 'S ENEMIES IN NEIGHBORHOOD N .
M_a		IN COOP, THE NOMINAL PERCENTAGE CHANGE IN COOPERATION/DAY DUE TO ACTIVITY A .
M_{ng}		IN JIN, MOOD FORCE MULTIPLIER
M_{mfg}		MAGNITUDE MULTIPLIER, WHEN SCHEDULING INDIRECT EFFECTS OF NSAT LEVEL AND SLOPE INPUTS.
$near_{mn}$		PREDICATE FOR $proximity_{mn}$ = "NEAR".
N_c	NC	IN NSAT, THE NUMBER OF CONCERNS.
N_g	NG	THE NUMBER OF GROUPS. THE PRECISE MEANING OF THIS SYMBOL DEPENDS ON THE CONTEXT; IT IS THE NUMBER OF GROUPS IN THE RELEVANT SET OF GROUPS. IN CIVSAT, FOR EXAMPLE, IT'S THE NUMBER OF CIVILIAN GROUPS. IN NSAT (SECTION ERROR! REFERENCE SOURCE NOT FOUND.) IT'S THE NUMBER OF GROUPS WHOSE SATISFACTION NSAT IS TRACKING.
N_n	NN	THE NUMBER OF NEIGHBORHOODS IN THE JNEM PLAYBOX.
$ncontrib_i(t_1)$	NCONTRIB	NOMINAL CONTRIBUTION-TO-DATE OF NSAT LEVEL OR SLOPE EFFECT I AT TIME STEP t_1 .
$\Omega_{nfg}(t)$	COOP.NFG	IN COOP, THE COOPERATION LEVEL BETWEEN GROUPS F AND G IN NEIGHBORHOOD N , THAT IS, THE LIKELIHOOD F WILL PROVIDE INTEL TO G .
$\Omega_{nfg}(0)$	COOP0.NFG	IN COOP, THE INITIAL COOPERATION LEVEL BETWEEN GROUPS F AND G IN NEIGHBORHOOD N , I.E., THE COOPERATION LEVEL AT SIMULATION TIME 0.
$\Delta\Omega_{nfg}(t_1)$		IN COOP, THE CHANGE IN $\Omega_{nfg}(t)$ AT TIME STEP t_1 .
P	P	THE NEAR FACTOR, WHEN SUBMITTING LEVEL OR SLOPE INPUTS TO NSAT.
P_i		IN JIN, NUMBER OF PERSONNEL IN UNIT I .
$population_{ng}$	POPULATION.NG	THE POPULATION OF GROUP G IN NEIGHBORHOOD N , AS DISTINCT FROM UNIT PERSONNEL. PROPERLY SPEAKING, ONLY

		CIVILIAN GROUPS HAVE POPULATION.
MATH SYMBOL	TEXT SYMBOL	DEFINITION
$proximity_{mn}$	PROXIMITY.MN	THE PROXIMITY OF NEIGHBORHOOD N TO NEIGHBORHOOD M FROM THE POINT OF VIEW OF RESIDENTS OF M . VALUES ARE 0, 1, 2, 3, FOR “HERE”, “NEAR”, “FAR”, AND “REMOTE”.
Q	Q	THE FAR FACTOR, WHEN SUBMITTING LEVEL OR SLOPE INPUTS TO NSAT.
Q_{ng}	OWN_FORCE.NG	IN JIN, GROUP G ’S “OWN FORCE” IN NEIGHBORHOOD N .
r_{ngef}	RATE.NGEF	THE EFFECTIVE RATE OF GENERATION, IN EVENTS/DAY, OF REACTIVE EVENT E BY GROUP G TARGETING GROUP F IN NEIGHBORHOOD N .
ra_{ngef}	RATEA.NGEF	THE ADJUSTED RATE OF GENERATION, IN EVENTS/DAY, OF REACTIVE EVENT E BY GROUP G TARGETING GROUP F IN NEIGHBORHOOD N .
rb_{ngef}	RATEB.NGEF	THE BASE RATE OF GENERATION, IN EVENTS/DAY, OF REACTIVE EVENT E BY GROUP G TARGETING GROUP F IN NEIGHBORHOOD N .
S_{ngc}	SAT.NGC	GROUP G ’S SATISFACTION WITH CONCERN C IN NEIGHBORHOOD N .
$S_{ngc}(t)$		GROUP G ’S SATISFACTION WITH CONCERN C IN NEIGHBORHOOD N AT TIME T .
$S_{ngc}(0)$		GROUP G ’S INITIAL SATISFACTION WITH CONCERN C IN NEIGHBORHOOD N , I.E., ITS SATISFACTION AT TIME 0.
$S(0)$		INITIAL SATISFACTION FOR AN ARBITRARY NEIGHBORHOOD, GROUP, AND CONCERN, I.E., SATISFACTION AT TIME 0.
S		SATISFACTION FOR AN ARBITRARY NEIGHBORHOOD, GROUP, AND CONCERN.
$S(t)$		SATISFACTION FOR AN ARBITRARY NEIGHBORHOOD, GROUP, AND CONCERN AT TIME T .
$S(0)$		INITIAL SATISFACTION FOR AN ARBITRARY NEIGHBORHOOD, GROUP, AND CONCERN, I.E., SATISFACTION AT TIME 0.
S_A		COMPOSITE SATISFACTION OVER S_{ngc} FOR SOME SUBSET A OF THE NEIGHBORHOODS, GROUPS, AND CONCERNS.
S_{gc}	SAT.GC	GROUP G ’S SATISFACTION WITH CONCERN C AT THE TOP LEVEL.

MATH SYMBOL	TEXT SYMBOL	DEFINITION
S_g	SAT.G	GROUP G 'S COMPOSITE SATISFACTION (MOOD) AT THE TOP LEVEL.
S_{ng}	SAT.NG	GROUP G 'S COMPOSITE SATISFACTION (MOOD) IN NEIGHBORHOOD N .
$\sigma_{ngc}(0)$	TREND0.NGC	THE LONG-TERM TREND FOR $S_{ngc}(t)$, IN SATISFACTION POINTS PER DAY.
$\sigma(0)$		THE LONG-TERM TREND FOR AN ARBITRARY NEIGHBORHOOD, GROUP, AND CONCERN.
$scontrib_i(t_1)$	SCONTRIB	SCALED NOMINAL CONTRIBUTION-TO-DATE OF NSAT LEVEL OR SLOPE EFFECT I AT TIME STEP t_1 .
$Security_{ng}$	SECURITY.NG	SECURITY OF GROUP G IN NEIGHBORHOOD N .
T		AN ARBITRARY SIMULATION TIME.
t_0, t_1		THE SIMULATION TIMES OF TWO SUCCESSIVE JNEM TIME STEPS.
t'_0, t'_1		THE START AND END TIMES FOR A SLOPE EFFECT BETWEEN TIMES t_0 AND t_1 .
TE	TE	END TIME OF AN NSAT LEVEL OR SLOPE EFFECT.
TS	TS	START TIME OF AN NSAT LEVEL OR SLOPE EFFECT.
τ	TAU	SHAPE PARAMETER FOR AN NSAT LEVEL EFFECT'S REALIZATION CURVE.
$TotalForce_n$		IN JIN, TOTAL FORCE IN NEIGHBORHOOD N , INCLUDING A FRACTION H OF NEARBY NEIGHBORHOODS.
$V_{g,HOSTILE}$	VOLUME.G	HOSTILE PERCENTAGE VOLUME FOR GROUP G .
V_{nge}	VOLUME.NGE	REACTIVE EVENT VOLUME FOR NEIGHBORHOOD N , GROUP G , AND REACTIVE EVENT TYPE E .
$Volatility_n$	VOLATILITY.N	IN JIN, VOLATILITY OF NEIGHBORHOOD N .
W_{ng}	ROLLUP_WEIGHT.NG	
Z_{ge}	ZEVENT.GE	GROUP G 'S Z-CURVE FOR THE BASE RATE OF REACTIVE EVENT E .
$Z_{g,HOSTILE}$	ZHOSTILE.G	GROUP G 'S Z-CURVE FOR THE BASE HOSTILE PERCENTAGE.

Appendix III – JNEM equations

Satisfaction level - a decimal number S , where $-100.0 \leq S \leq +100.0$

Rating satisfaction scale

SYMBOL	MEANING	MIDPOINT	RANGE
VS	VERY SATISFIED	80.0	$60.0 < S \leq 100.0$
S	SATISFIED	40.0	$20.0 < S \leq 60.0$
A	AMBIVALENT	0.0	$-20.0 < S \leq 20.0$
D	DISSATISFIED	-40.0	$-60.0 < S \leq -20.0$
VD	VERY DISSATISFIED	-80.0	$-100.0 \leq S \leq -60.0$

Population - A group g is said to reside in neighborhood n if $population_{ng} > 0$

Concerns - The satisfaction of group g in neighborhood n with respect to concern c is denoted S_{ngc} .

Saliency - Saliency is represented by a number L_{ngc} where $0.0 \leq L_{ngc} \leq 1.0$.

Saliency scale

SYMBOL	MEANING	VALUE
CR	CRUCIAL	1.00
VI	VERY IMPORTANT	0.85
I	IMPORTANT	0.70
LI	LESS IMPORTANT	0.55
UN	UNIMPORTANT	0.40
NG	NEGLIGIBLE	0.00

Roll-up weight - *rollup weight* of group g in neighborhood n , denoted by W_{ng} .

Satisfaction values weighted with the saliency: $\hat{S}_{ngc} = L_{ngc} \times S_{ngc}$

“Rolls up” satisfaction across any set A of neighborhoods, groups, and concerns:

$$S_A = \frac{\sum_A W_{ng} \cdot L_{ngc} \cdot S_{ngc}}{\sum_A W_{ng} \cdot L_{ngc}}$$

Mood of each group g in each neighborhood n : $S_{ng} = \frac{\sum_c W_{ng} \cdot L_{ngc} \cdot S_{ngc}}{\sum_c W_{ng} \cdot L_{ngc}}$

The **top level or playbox satisfaction** of each group g with each concern c :

$$S_{gc} = \frac{\sum_n W_{ng} \cdot L_{ngc} \cdot S_{ngc}}{\sum_n W_{ng} \cdot L_{ngc}}$$

The top level or *playbox mood* of each group g : $S_g = \frac{\sum_n \sum_c W_{ng} \cdot L_{ngc} \cdot S_{ngc}}{\sum_n \sum_c W_{ng} \cdot L_{ngc}}$

Satisfaction curve - The satisfaction for group g in neighborhood n with respect to concern c at time t is denoted $S_{ngc}(t)$, often abbreviated S_{ngc}

Initial satisfaction - is denoted $S_{ngc}(0)$

Computing satisfaction –

$$S(t_1) = S(0) + (\text{contributions from } 0 \text{ to } t_1)$$

$$S(t_2) = S(t_1) + (\text{contributions from } t_1 \text{ to } t_2)$$

$\vdots$

Scaled contribution – for each nominal contribution apply the following equation

$$\text{scale}(ncontrib) = \begin{cases} 2 \cdot \frac{100 - S(t_0)}{200} \cdot ncontrib & \text{where } ncontrib \geq 0 \\ 2 \cdot \frac{100 + S(t_0)}{200} \cdot ncontrib & \text{where } ncontrib < 0 \end{cases}$$

Long term trend – is denoted, $\sigma_{ngc}(0)$,

Contribution of long-term trend $\sigma(0)$ to $S(t_1)$ over the interval from t_0 to t_1 is

therefore $\sigma(0) \cdot (t_1 - t_0)$

Scaled long-term trend - $S(t_1) = S(t_0) + \text{scale}(\sigma(0) \cdot (t_1 - t_0))$

Level Effects:

- n , the affected neighborhood
- g , the affected group
- c , the affected concern
- k , an indicator of the effect's cause
- $limit$, the nominal magnitude of the satisfaction change
- $days$, the time interval in days over which the effect is realized
- ts , the effect's start time
- te , the effect's end time.
- τ , a parameter which controls the shape of the realization curve.
-
- **Realization curve** for a level effect is defined by the following function $E(t)$:

$$E(t) = \begin{cases} 0 & t \leq ts \\ limit \cdot \left(1.0 - e^{\frac{-(t-ts)}{\tau}} \right) & ts < t < te \\ limit & t \geq te \end{cases}$$

$E_i(t)$ denotes this function for a specific level effect i . The nominal contribution to satisfaction of level effect i at timestep t_1 is therefore $\delta_i(t_1, t_0) = E_i(t_1) - E_i(t_0)$

Satisfaction level at timestep t_1 is

$$S(t_1) = S(t_0) + \text{scale} \left(\sum_i \delta_i(t_1, t_0) \right)$$

As the simulation runs from timestep to timestep, we accumulate the nominal and scaled contributions to date for each level effect, $ncontrib_i(t)$ and $scontrib_i(t)$. In particular,

$$ncontrib_i(t_1) = ncontrib_i(t_0) + \delta_i(t_1, t_0)$$

$$scontrib_i(t_1) = scontrib_i(t_0) + \text{scale}(\delta_i(t_1, t_0))$$

The **nominal contribution** of the effects with cause k is then

$$\max_{i \in I_k^+} \delta_i(t_1, t_0) + \min_{i \in I_k^-} \delta_i(t_1, t_0)$$

NSAT inputs for which no cause is specified as having a unique cause k , then the satisfaction level at timestep t_1 is

$$S(t_1) = S(t_0) + \text{scale} \left(\sum_k \max_{i \in I_k^+} \delta_i(t_1, t_0) + \min_{i \in I_k^-} \delta_i(t_1, t_0) \right)$$

the effect's **actual contribution** during the timestep:

$$acontrib_i(t_1) = acontrib_i(t_0) + \begin{cases} \frac{\delta_i(t_1, t_0)}{\sum_{j \in I_k^+} \delta_j(t_1, t_0)} \cdot \max_{j \in I_k^+} \delta_j(t_1, t_0) & \text{if } i \in I_k^+ \\ \frac{\delta_i(t_1, t_0)}{\sum_{j \in I_k^-} \delta_j(t_1, t_0)} \cdot \min_{j \in I_k^-} \delta_j(t_1, t_0) & \text{if } i \in I_k^- \end{cases}$$

Slope Effects:

- *sitId*, the situation identifier
- *n*, the affected neighborhood
- *g*, the affected group
- *c*, the affected concern
- *k*, an indicator of the effect's cause
- *slope*, the nominal change per day
- *limit*, the maximum nominal contribution for this effect.
- *ts*, the effect's start time
- *te*, the effect's end time

Nominal contribution of a slope effect i for time step t_1

$$\phi_i(t_1, t_0) = slope \cdot (t_1 - t_0)$$

nominal contribution to date at time t_1 is simply the nominal contribution to date at time t_0 plus the nominal contribution made from t_0 to t_1 :

$$ncontrib_i(t_1) = ncontrib_i(t_0) + \phi_i(t_1, t_0)$$

$ncontrib_i(t_1)$ that must not exceed *limit*. Consequently,

$$\phi_i(t_1, t_0) = \min[limit - ncontrib_i(t_0), slope \cdot (t_1 - t_0)]$$

Full formula for slope effects

$$\phi_i(t_1, t_0) = \begin{cases} \min limit - ncontrib_i(t_0), slope \cdot (t_1 - t_0), & \text{where } ts < t_1 \text{ and } te > t_0 \\ 0, & \text{otherwise} \end{cases}$$

Disregarding level effects and the long-term trend, the satisfaction level at timestep t_1 is therefore

$$S(t_1) = S(t_0) + scale \left(\sum_i \phi_i(t_1, t_0) \right)$$

Accumulate the **nominal and scaled contributions to date for each slope effect**, $ncontrib_i(t)$ and $scontrib_i(t)$. In particular,

$$ncontrib_i(t_1) = ncontrib_i(t_0) + \phi_i(t_1, t_0)$$

$$scontrib_i(t_1) = scontrib_i(t_0) + scale(\phi_i(t_1, t_0))$$

The nominal contribution of the effects with cause k is then

$$\max_{i \in I_k^+} \phi_i(t_1, t_0) + \min_{i \in I_k^-} \phi_i(t_1, t_0)$$

If we treat NSAT inputs for which no cause is specified as having a unique cause k , then the satisfaction level at timestep t_1 (disregarding level effects and the long term trend) is

$$S(t_1) = S(t_0) + \text{scale} \left(\sum_k \max_{i \in I_k^+} \phi_i(t_1, t_0) + \min_{i \in I_k^-} \phi_i(t_1, t_0) \right)$$

the effect's **actual contribution** during the timestep:

$$acontrib_i(t_1) = acontrib_i(t_0) + \begin{cases} \frac{\phi_i(t_1, t_0)}{\sum_{j \in I_k^+} \phi_j(t_1, t_0)} \cdot \max_{j \in I_k^+} \phi_j(t_1, t_0) & \text{if } i \in I_k^+ \\ \frac{\phi_i(t_1, t_0)}{\sum_{j \in I_k^-} \phi_j(t_1, t_0)} \cdot \min_{j \in I_k^-} \phi_j(t_1, t_0) & \text{if } i \in I_k^- \end{cases}$$

Proximity Table

VALUE	SYMBOL	NOTES
0	HERE	$m = n$; INDIRECT EFFECTS ALWAYS OCCUR.
1	NEAR	N IS NEAR M ; INDIRECT EFFECTS ARE COMMON.
2	FAR	N IS FAR FROM M ; INDIRECT EFFECTS ARE RARE.
3	REMOTE	N IS REMOTE FROM M ; INDIRECT EFFECTS NEVER OCCUR.

$$\begin{aligned} here_{mn} &= \begin{cases} 1 & \text{if } proximity_{mn} = 0 \\ 0 & \text{if } proximity_{mn} \neq 0 \end{cases} \\ near_{mn} &= \begin{cases} 1 & \text{if } proximity_{mn} = 1 \\ 0 & \text{if } proximity_{mn} \neq 1 \end{cases} \\ far_{mn} &= \begin{cases} 1 & \text{if } proximity_{mn} = 2 \\ 0 & \text{if } proximity_{mn} \neq 2 \end{cases} \end{aligned}$$

Magnitude multiplier: for group g and concern c in neighborhood n

$$M_{mfg} = R_{mfg} \cdot (here_{mn} + p \cdot E_{ng} \cdot near_{mn} + q \cdot E_{ng} \cdot far_{mn})$$

variables p and q , also known as the *near factor* and the *far factor* respectively, are multipliers specified as part of the NSAT input. Each is a fraction ranging from 0.0 to 1.0

E_{ng} , the *effects factor*, is a multiplier, nominally 1.0, which can be used to increase or decrease the importance of neighborhood group ng to the rest of the playbox.

R_{mfg} is the *relationship* between group f and group g in neighborhood m ; it is a number between -1.0 and $+1.0$, where $+1.0$ indicates that f and g are perfect friends and -1.0 indicates that f and g are perfect enemies.

. First, the direct effect is: $\{n, g, c, limit, ts, te\}$

Indirect effects in neighborhood n are defined by

$\{n, f, c, M_{nfg} \cdot limit, ts, te\}$ for all f resident in n , $f \neq g$

$\{n, f, c, R_{nfg} \cdot limit, ts, te\}$ for all f resident in n , $f \neq g$

Indirect effects in nearby neighborhoods are defined by

$\{m, f, c, M_{mfg} \cdot limit, ts + delay_{mn}, te + delay_{mn}\}$

for all f resident in all m where $near_{mn} = 1$, or, equivalently,

$\{m, f, c, p \cdot E_{ng} \cdot R_{mfg} \cdot limit, ts + delay_{mn}, te + delay_{mn}\}$

for all f resident in all m where $near_{mn} = 1$.

Indirect effects in faraway neighborhoods are defined by

$\{m, f, c, M_{mfg} \cdot limit, ts + delay_{mn}, te + delay_{mn}\}$

for all f resident in all m where $far_{mn} = 1$, or, equivalently,

$\{m, f, c, q \cdot E_{ng} \cdot R_{mfg} \cdot limit, ts + delay_{mn}, te + delay_{mn}\}$

for all f resident in all m where $far_{mn} = 1$.

Cooperation table

NARRATIVE	SYMBOL	Ω , %	RANGE, %		
ALWAYS COOPERATIVE	AC	100.0	99.	$\Omega \leq$	100.0
VERY COOPERATIVE	VC	90.0	80	$\Omega <$	99.9
COOPERATIVE	C	70.0	60	$\Omega <$	80.0
MARGINALLY COOPERATIVE	MC	50.0	40.	$\Omega <$	60.0
UNCOOPERATIVE	U	30.0	20.	$\Omega <$	40.0
VERY UNCOOPERATIVE	VU	10.0	1.0	$\Omega <$	20.0
NEVER COOPERATIVE	NC	0.0	0.0	$\Omega <$	1.0

Adjusted percentage change in cooperation per day is therefore

$$\Delta C_{nfga} = Coverage_{nga} \times RMF_a(R_{nfg}) \times M_a$$

The RMF takes the nominal relationship into account automatically; however, the nominal coverage must be allowed for explicitly

$$\Delta C_{nfga} = \frac{Coverage_{nga}}{NomCoverage} \times RMF_a(R_{nfg}) \times M_a$$

The nominal cooperation change, in percentage points per day, between two arbitrary groups f and g in neighborhood n due to the distribution of supply type y is therefore

$$\Delta C_{nfgy} = \begin{cases} \Delta C1_{nfgy} + \Delta C2_{nfgy} + \Delta C3_{nfgy} & \text{where } f \text{ is civilian and } g \text{ is force} \\ 0 & \text{otherwise} \end{cases}$$

$\Delta C1_{nfgy}$, then, is the change in cooperation when force group g is donating supplies of type y to civilian group f for distribution in neighborhood n :

$$\Delta C1_{nfgy} = \begin{cases} \text{frmore}(R_{nfg}) \times M1_y & \text{where } g \text{ is donating } y \text{ to } f \text{ in } n \\ 0 & \text{otherwise} \end{cases}$$

$\Delta C2_{nfy}$ is the change in cooperation between donating force group g and recipient civilian group f when g is donating supplies of type y that are then being consumed by f in mitigation of one or more abstract situations in neighborhood n :

$$\Delta C2_{nfy} = \begin{cases} \frac{DrawFraction_{nf}}{NominalDF} \times \text{frmore}(R_{nfg}) \times M2_y & \text{where } g \text{ is donating } y \text{ to } f \text{ in } n, \\ & \text{and } f \text{ is consuming } y \\ 0 & \text{otherwise} \end{cases}$$

nominal draw fraction, $NominalDF$.

$$NominalDF = \frac{lo + hi}{2}$$

$\Delta C3_{nfy}$ is the change in cooperation between distributing force group g and recipient civilian group f when g is distributing supplies of type y to f , which is consuming them in mitigation of one or more abstract situations in neighborhood n :

$$\Delta C3_{nfy} = \begin{cases} \frac{DrawFraction_{nf}}{NominalDF} \times \text{frmore}(R_{nfg}) \times M3_y & \text{where } g \text{ is distributing } y \text{ to } f \text{ in } n, \\ & \text{and } f \text{ is consuming } y \\ 0 & \text{otherwise} \end{cases}$$

Nominal change to cooperation, in percentage points per day, is the sum of the effects of unit activities and the distribution of supplies:

$$\Delta C_{nfg} = \sum_a \Delta C_{nfga} + \sum_y \Delta C_{nfy}$$

The total indirect effect on civilian group f 's cooperation with force group g is $\Delta C'_{nfg}$, which is defined as follows:

$$\Delta C'_{nfg} = \sum_{h \in G_{FRC}, h \neq g} R_{ngh} \times \Delta C_{nfh}$$

The total nominal change is therefore $\Delta C_{nfg} + \Delta C'_{nfg}$. Note that if R_{ngg} is 1.0, as is usually the case, then

$$\Delta C_{nfg} + \Delta C'_{nfg} = \sum_{h \in G_{FRC}} R_{ngh} \times \Delta C_{nfg}$$

As with satisfaction changes, the actual change in cooperation during the time step from t_0 to t_1 due to g 's activity should show diminishing marginal utility, and is therefore given by

$$\Delta \Omega_{nfg}(t_1) = (\Delta C_{nfg} + \Delta C'_{nfg}) \cdot (t_1 - t_0) \cdot \begin{cases} \frac{100 - \Omega_{nfg}(t_0)}{100} & \text{if } \Delta C_{nfg} + \Delta C'_{nfg} \geq 0 \\ \frac{\Omega_{nfg}(t_0)}{100} & \text{if } \Delta C_{nfg} + \Delta C'_{nfg} < 0 \end{cases}$$

The cooperation level $\Omega_{nfg}(t_1)$ is therefore

$$\Omega_{nfg}(t_1) = \Omega_{nfg}(t_0) + \Delta \Omega_{nfg}(t_1)$$

Measuring Force

group g 's own force in neighborhood n is

$$Q_{ng} = F_{ng} \times \text{population}_{ng} + \sum_{\substack{\text{Unit } i \text{ of group } g \\ \text{in neighborhood } n}} F_i \times \text{personnel}_i$$

F_{ng} is a force multiplier which is defined as follows:

$$F_{ng} = a \cdot D_{ng} M_{ng}$$

D_{ng} is a multiplier based on the demeanor of g in neighborhood n

$$D_{ng} = \begin{cases} 1.5 & \text{if demeanor is Aggressive} \\ 1.0 & \text{if demeanor is Average} \\ 0.3 & \text{if demeanor is Apathetic} \end{cases}$$

M_{ng} is a multiplier based on the mood S_{ng} of group g in neighborhood n

$$M_{ng} = \left(1 - b \cdot \frac{S_{ng}}{100}\right)$$

F_i is intended to account for the effectiveness and demeanor of the unit's personnel:

$$F_i = E_i D_{ng}$$

E_i will be determined more simply, as shown in the following table:

CHARACTERISTICS OF UNIT I			E_I
UNIT'S GROUP TYPE IS CIVILIAN (CIV)	UNIT'S HOSTILITY_LEVEL IS:	NON_HOSTILE	1
		SUPPORTER	2
		COMBATANT	4
UNIT'S GROUP TYPE IS ORGANIZATION (ORG)	GROUP'S ORG TYPE IS:	NGO	0
		IGO	0
		CONTRACTOR	2
UNIT'S GROUP TYPE IS FORCE (FRC)	GROUP'S FORCE TYPE IS:	REGULAR	25
		PARAMILITARY	15
		POLICE	10
		IRREGULAR	20
		CRIMINAL	8

Group Relationship Matrix, R_{nfg}

$$R_{nfg}^+ = \begin{cases} R_{nfg} & \text{where } R_{nfg} > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad R_{nfg}^- = \begin{cases} |R_{nfg}| & \text{where } R_{nfg} < 0 \\ 0 & \text{otherwise} \end{cases}$$

$$LocalFriends_{ng} = \sum_f Q_{nf} R_{nfg}^+$$

$$LocalEnemies_{ng} = \sum_f Q_{nf} R_{nfg}^-$$

nearby neighborhoods into account

$$Force_{ng} = LocalFriends_{ng} + h \cdot \sum_{m \text{ near } n} LocalFriends_{mg}$$

$$Enemy_{ng} = LocalEnemies_{ng} + h \cdot \sum_{m \text{ near } n} LocalEnemies_{mg}$$

In order to create scores, we'll need to normalize these values by the total force in the neighborhood:

$$TotalForce_n = \sum_g Q_{ng} + h \cdot \sum_{m \text{ near } n} \sum_g Q_{mg}$$

$$\%Force_{ng} = \frac{Force_{ng}}{TotalForce_n} \times 100$$

$$\%Enemy_{ng} = \frac{Enemy_{ng}}{TotalForce_n} \times 100$$

Volatility

$$Conflicts_n = \sum_g Enemy_{ng} \cdot Force_{ng}$$

$$Volatility_n = \frac{Conflicts_n}{TotalForce_n^2} \times 100$$

The security of group g in neighborhood n is defined as follows:

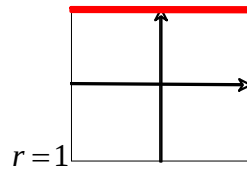
$$Security_{ng} = \frac{\%Force_{ng} - \%Enemy_{ng} - v \cdot Volatility_n}{100 + v \cdot Volatility_n} \times 100$$

Security table

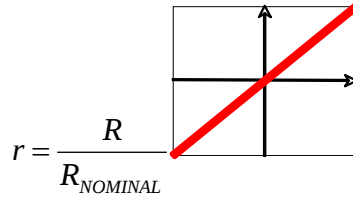
RANGE	SYMBOL
$25 < Security_{ng} \leq 100$	HIGH
$5 < Security_{ng} \leq 25$	MEDIUM
$-25 < Security_{ng} \leq 5$	LOW
$Security_{ng} \leq -25$	NONE

Relationship Multiplier Functions (RMFs)

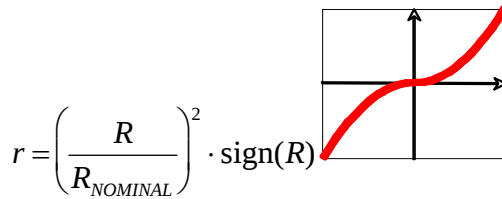
Constant



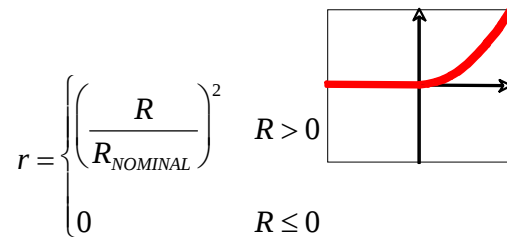
Linear:



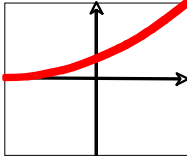
Quad:



Friends Quad:

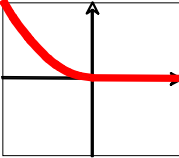


Friends More:

$$r = \left(\frac{1+R}{1+R_{NOMINAL}} \right)^2$$


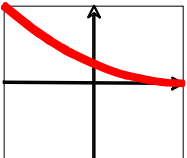
A graph showing a red curve in the first quadrant of a Cartesian coordinate system. The curve starts at a positive value on the vertical axis and increases as it moves to the right, representing an increasing function of R.

Enemies Quad:

$$r = \begin{cases} \left(\frac{R}{R_{NOMINAL}} \right)^2 & R < 0 \\ 0 & R \geq 0 \end{cases}$$


A graph showing a red curve in the second quadrant of a Cartesian coordinate system. The curve starts at a high value on the vertical axis and decreases as it moves to the right, approaching the horizontal axis. For R ≥ 0, the value of r is 0, represented by a horizontal line along the positive horizontal axis.

Enemies More:

$$r = \left(\frac{1-R}{1+R_{NOMINAL}} \right)^2$$


A graph showing a red curve in the second quadrant of a Cartesian coordinate system. The curve starts at a high value on the vertical axis and decreases as it moves to the right, approaching the horizontal axis, representing a decreasing function of R.

Force Abstract Activities

ACTIVITY	WHILE MOVING?	MINIMUM SECURITY REQUIRED	COVERAGE FUNCTION
PRESENCE	N/A	N/A	25/1000
COMBAT	N/A	N/A	1/1000
CHECKPOINT/CONTROL POINT	NO	LOW	25/1000
CMO – CONSTRUCTION	NO	HIGH	20/1000
CMO – DEVELOPMENT (LIGHT)	NO	MEDIUM	25/1000
CMO – EDUCATION	NO	HIGH	20/1000
CMO – EMPLOYMENT	NO	HIGH	20/1000
CMO – HEALTHCARE	NO	HIGH	20/1000
CMO – INDUSTRY	NO	HIGH	20/1000
CMO – INFRASTRUCTURE	NO	HIGH	20/1000
CMO – LAW ENFORCEMENT	NO	MEDIUM	25/1000
CMO – OTHER	NO	HIGH	20/1000
COERCION	NO	MEDIUM	12/1000
CORDON AND SEARCH	NO	MEDIUM	25/1000
CRIMINAL ACTIVITIES	YES	MEDIUM	10/1000
CURFEW	YES	MEDIUM	25/1000
GUARD	NO	LOW	25/1000
INTERVIEW/SCREEN	YES	MEDIUM	25/1000
PATROL	YES	LOW	25/1000
PSYOP	YES	MEDIUM	1/50000

In order to determine **coverage fraction**

$$\text{troop density } TD = \frac{p \cdot d}{\text{Population}_n}$$

where p is the number of personnel engaged in the activity. Then, the **coverage fraction**

is

$$CF = 1 - e^{-\frac{TD \cdot \ln 3}{c}}$$

Example: Force group g has 750 troops in neighborhood n , which has a total population of 40,000 people:

$$p = 750$$

$$Population_n = 40,000$$

The coverage fraction parameter, c/d , is nominally 25/1000 for mere presence. The asset density for group g is therefore

$$TD = \frac{p \cdot d}{Population_n} = \frac{750 \cdot 1,000}{40,000} = \frac{750}{40} = 18.75$$

The coverage fraction is therefore

$$1 - e^{-\frac{18.75 \ln 3}{25}} = 1 - e^{-0.824} = 1 - 0.44 = 0.56$$

Composite coverage fraction

$$Coverage_{na} = 1 - \prod_g (1 - Coverage_{nga})$$

Facility and Situation Types

SITE TYPE	REPRESENTS	CAN SPAWN
CB.WARFR.PROD.FCL	CHEMICAL & BIOLOGICAL WARFARE PRODUCTION FACILITY	DISEASE, BADFOOD, BADWATER
CHEMICAL.PLNT	CHEMICAL PLANT (RAW MATERIAL PRODUCTION AND/OR STORAGE)	INDSPILL
ELECTRIC.SUBSTN	ELECTRIC POWER SUBSTATION (ELECTRO/OPTICAL)	POWEROUT
ELEC.PWR.PLNT.DAM	ELECTRIC POWER PLANT DAM	POWEROUT
ELEC.PWR.PLT.FSFL	ELECTRIC POWER FACILITY (FOSSIL FUEL)	POWEROUT
FOOD.DISTRIBUTION	FOOD DISTRIBUTION (COULD BE FINISHED PRODUCT OR GRAIN ELEVATOR, ETC)	DISEASE, BADFOOD, FOODSHRT
HOSPITAL	HOSPITAL (FULL UP LIKE NORMAL LARGE CITY HOSPITAL)	DISEASE
MED.TRETMT.FACLT	MEDICAL TREATMENT FACILITY (DOCTOR'S OFFICE SPECIAL MEDICAL FACILITIES)	DISEASE
MOSQUE	MOSQUE, CHURCH, OTHER RELIGIOUS FACILITY	MOSQUE
NUCLEAR.PWR.PLNT	NUCLEAR POWER PLANT	DISEASE, BADFOOD, BADWATER
NUCLR.MTL.PRD.FCL	NUCLEAR MATERIAL PRODUCTION FACILITY	DISEASE, BADFOOD, BADWATER
OIL.PUMP.STATN	MAIN LINE PUMPING STATION FOR OIL (MOVES THE OIL DOWN THE PIPELINE)	PIPELINE, FUELSHRT
POWER.PLANT	POWER PLANT – ELECTRIC	POWEROUT
RAW.MTRL.PRD.STOR	RAW MATERIAL PRODUCTION & STORAGE	INDSPILL
REFINERY	PETROLEUM, OIL, OR GAS REFINERY	REFINERY, FUELSHRT
SEWAGE.TRETMT.FCL	SEWAGE PLANT	DISEASE, BADWATER, NOWATER
TELECOMMS.FACLT	TELECOMMUNICATIONS FACILITY	COMMOUT
WATER.PLNT	WATER PLANT – PUBLIC WATER SERVICES (ANY TYPE-DRILLING, CLEANING, DESALINIZATION, ETC)	NOWATER

Distribution of supplies

TYPE	DESCRIPTION	MITIGATES ABSTRACT SITUATIONS
CONSTRUCTION	CONSTRUCTION SUPPLIES (CLASS IV)	ANY
FOOD	FOOD (CLASS I)	BADFOOD, FOODSHRT
MEDICAL	MEDICAL SUPPLIES (CLASS VIII)	DISEASE, EPIDEMIC
POL	PETROLEUM/OIL/LUBRICANT (CLASS III)	FUELSHRT
WATER	WATER (CLASS I)	BADWATER, NOWATER

The following notation is used

i = A particular distribution of supplies in the playbox

n_i = The neighborhood in which i is located.

D_i = The donor, which may be any group

d_i = The distributor, which may be any group

G_i = The set of recipients, which must all be civilian groups resident in

neighborhood n_i

$f \in G_i$ = A particular recipient of supplies from distribution i .

y = A supply type

$Stock_{iy}$ = The quantity of supply type y , in tons, available for consumption by the recipients from distribution i .

W_{sy} = The maximum per capita consumption rate of supply type y , in tons/day per person, consumed by recipients to mitigate abstract situation s .

A_{ny} = The set of abstract situations currently active in neighborhood n whose effects are mitigated by supplies of type y .

The **actual consumption per capita** depends on the group's draw fraction, $DrawFraction_{nf}$, a value between 0.0 and 1.0 which is derived from group f 's security in neighborhood n :

$$DrawFraction_{nf} = Z_{drawfraction}(Security_{nf})$$

Group f then draws y from available stock at the following rate:

$$GroupDrawRate_{nfy} = DrawFraction_{nf} \cdot Population_{nf} \cdot \sum_{s \in A_{ny}} W_{sy}$$

. Supplies of type y will therefore be drawn from distribution i at the following rate:

$$DrawRate_{iy} = \sum_{f \in G_i} \frac{GroupDrawRate_{nfy}}{N_{nfy}}$$

The **shrinkage rate** is therefore

$$ShrinkageRate_y = Stock_{iy} \cdot Z_{shrinkage}(\max(Security_{nD}, Security_{nd}))$$

The **total consumption rate**, in tons/day, for supply type y from distribution i is therefore

$$TotalConsumptionRate_{iy} = DrawRate_{iy} + ShrinkageRate_{iy}$$

The **actual consumption** of y from i during a time step is therefore

$$Stock_{iy}(t_1) = Stock_{iy}(t_0) - \min(Stock_{iy}(t_0), TotalConsumptionRate_{iy} \cdot (t_1 - t_0))$$

Satisfaction Implication

$$\Delta S_{nfc} = DrawFraction_{nf} \times RMF_{syc}(R_{nfd}) \times M_{syc}$$

The nominal satisfaction change then becomes

$$\Delta S_{nfc} = \frac{DrawFraction_{nf}}{NominalIDF} \times RMF_{sync}(R_{nfd}) \times M_{sync}$$

Security Checkpoint Coverage

$n =$ A neighborhood

$g =$ A force group

$i =$ A security checkpoint belonging to g in n

$t =$ The current simulation time

$ts_i =$ The start time of checkpoint i (MRF) or the time when it became known

to JNEM (ERF).

$P_i =$ Number of personnel manning checkpoint i .

$A_i =$ The "age factor", a multiplier that decreases the effect of temporary

checkpoints as they age.

$W_i =$ The "weight" of a checkpoint

$scpPersonnel_{ng} =$ The effective number of group g personnel manning checkpoints

in neighborhood n .

$scpCoverage_{ng} =$ The coverage fraction of group g 's security checkpoints

in neighborhood n .

Effective number of personnel manning g 's checkpoints in n , weighting the actual number by the permanence and intrusiveness of the checkpoint, and for temporary checkpoints the age as well:

$$scpPersonnel_{ng} = \sum_i P_i \times W_i \times A_i$$

Weighting table

	PERMANENT	TEMPORARY
LIGHT	−1 STOP	+ 0 STOPS
MEDIUM	BASE CASE	+1 STOP
HEAVY	+1 STOP	+2 STOPS

Weighting table

	PERMANENT	TEMPORARY
LIGHT	0.67	1.00
MEDIUM	1.00	1.50
HEAVY	1.50	2.25

the **age factor** is defined as follows:

$$A_i = \begin{cases} Z_{agefactor}(t - ts_i), & \text{when } i \text{ is temporary} \\ 1.0, & \text{when } i \text{ is permanent} \end{cases}$$

The coverage fraction is then

$$scpCoverage_{ng} = f(scpPersonnel_{ng})$$

Managing the Hostile Percentage

At each major timestep, JOUT computes the desired (h_g) and actual (h'_g) hostile percentages for group g ; these range from 0.0 to 100.0. It may then make a single unit hostile or non-hostile:

$$\text{If } h'_g < h_g - \varepsilon,$$

Make a non-hostile unit of group g hostile:

Determine whether it should be a combatant or a supporter.

Select the potentially hostile unit to be made hostile.
Else, if $h'_g > h_g + \varepsilon$,
Make a hostile unit of group g non-hostile.

The **actual hostile percentage**, h'_g , is simply the total personnel in group g 's hostile units divided by the total personnel in g 's potentially hostile units:

$$h'_g = 100.0 \cdot \frac{\sum_{u \in H_g} \text{personnel}_u}{\sum_{u \in PH_g} \text{personnel}_u}$$

The **desired hostile percentage**, h_g , is simply the actual hostile percentage we would like to have given group g 's satisfaction levels and other factors. h_g is computed as follows. First, the *base hostile percentage*, hb_g , is computed as a function of the group's playbox-wide mood by means of a Z-curve function

$$hb_g = Z_{g,HOSTILE}(S_g)$$

Next, a rule set is applied to adjust the base percentage, producing the *adjusted hostile percentage*, ha_g . Finally, the adjusted percentage is multiplied by a *volume control* to produce the desired hostile percentage, h_g . The volume control is an arbitrary non-negative number, nominally 1.0, which may be set by the JNEM tech controller. The volume control thus allows EXCON to adjust the desired percentage up or down while still allowing it to vary with the group's mood:

$$h_g = V_{g,HOSTILE} \cdot ha_g$$

Combatants vs. Supporters

When it is time to make a unit hostile, JOUT determines whether or not there are more than enough supporters for the existing combatants. If there are, the new hostile will be a combatant; otherwise it will be a supporter

$$\text{If } supporters_g > \frac{1 - comfrac_g}{comfrac_g} \cdot combatants_g, \\ \text{Enable a new combatant. Otherwise, enable a new supporter.}$$

JOUT uses similar logic when it is time to make a hostile unit non-hostile:

$$\text{If } supporters_g > \frac{1 - comfrac_g}{comfrac_g} \cdot combatants_g, \\ \text{Disable a supporter, if possible, and a combatant otherwise. Otherwise, disable a combatant, if possible, and a supporter otherwise.}$$

Selecting a new Hostile Unit

JOUT's algorithm for selecting units to be made hostile addresses both of these forces by means of a two-step process. First, JOUT randomly chooses the neighborhood; next JOUT randomly chooses a potentially-hostile unit within that neighborhood and makes it hostile. The units within the chosen neighborhood are equally likely to be chosen; the neighborhoods, however, are not. Instead, each neighborhood is assigned a probability, which is computed as follows.

First, each neighborhood is assigned a relative frequency:

$$freq_{ng} = \left(1 + \sum_{e \in MISSIONS} rate_{nge} \right) \cdot candidates_{ng}$$

$$P(\text{choosing neighborhood } n) = \frac{freq_{ng}}{\sum_n freq_{ng}}$$

Generating Reactive Events

The rate, in events per day, of reactive event type e for civilian or organization group g in neighborhood n is called r_{ngef} . For event types with explicit targeting, f is the targeted group; for other event types, f is ignored. r_{ngef} is computed as follows. First, the *base rate* is computed as a function of the group's mood in the neighborhood by means of a Z-curve function

$$rb_{ngef} = Z_{ge}(S_{ng})$$

$$ra_{ngef} = \text{ruleset}_e(rb_{ngef}, \dots)$$

the adjusted rate is multiplied by a *volume control* to produce the *effective rate*.

$$r_{ngef} = V_{ngef} \cdot ra_{ngef}$$

Explaining Changes to Satisfaction Levels

Thus, the contribution of event e to S_{ngc} over the time window from t_0 to t_1 is simply

$$acontrib_{engc}(t_0, t_1) = \sum_{t_0 \leq t \leq t_1} acontrib_{engct}$$

Importance of Events and Situations

Different groups assign different levels of importance to different concerns; this is the saliency, L_{ngc} . In addition, some groups are important than others; this is indicated by the rollout weight, W_{ng} . Taking both these factors into account, then, the importance of event e with respect to curve S_{ngc} is

$$imp_{engc}(t_0, t_1) = L_{ngc} \times W_{ng} \times acontrib_{engc}(t_0, t_1)$$

$$\begin{aligned} E &= \{e \text{ caused by BLUE}\} \\ C &= \{N1\} \times \{\text{all } g\} \times \{\text{all } c\} \end{aligned}$$

First, if E contains a single event and C contains a single curve, the equation should reduce to that shown above (for simplicity's sake, we drop the time window)

$$imp_{engc} = L_{ngc} \times W_{ng} \times acontrib_{engc}$$

If we have multiple events in E but C contains a single curve, then again, we should accumulate across the events and allow positive and negative terms to cancel:

$$imp_{Engc} = \sum_{e \in E} imp_{engc}$$

When we are looking at a single curve, it's reasonable to allow positive and negative terms to cancel out; but when looking across curves it is not. An actual change of 10 points to one curve and of -10 points to another isn't the same as a change of 0 points overall, even if both curves are for the same group g . If they are for different groups, or worse in different neighborhoods, then allowing them to cancel is clearly wrong. The classic approach, here, is to accumulate a sum of squares. The importance of a set of events E with respect to a set of satisfaction curves C is therefore:

$$imp_{EC} = \sqrt{\sum_{n,g,c \in C} \left(\sum_{e \in E} imp_{engc} \right)^2}$$

Note that if E contains one event e , and C contains one curve n,g,c , then

$$imp_{EC} = \sqrt{imp_{engc}^2} = imp_{engc}$$

Projected Importance

$$impproj_{engc} = L_{ngc} \times W_{ng} \times (acontrib_{engc} + fcontrib_{engc})$$

The only new term is $fcontrib_{engc}$, the **estimated future contribution** of event e to curve S_{ngc} . This, in turn is simply the sum of the future contributions of all direct and indirect effects i that contribute to S_{ngc} for event e :

$$fcontrib_{engc} = \sum_{i \in engc} fcontrib_i$$

For level effects, the future contribution is defined as follows:

$$fcontrib_i = \text{scale}(\text{limit}_i - ncontrib_i)$$

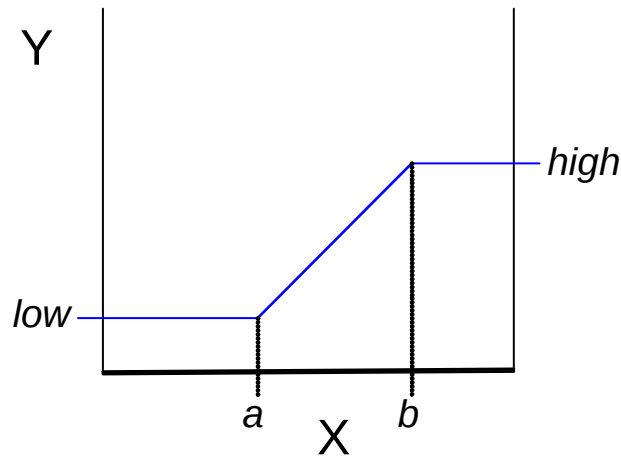
Consequently, we need to define some kind of time horizon, and estimate the future contribution within that time horizon, unless the limit will be reached earlier. The effective time horizon is therefore:

$$horizon = \min\left(NominalHorizon, \frac{\text{limit}_i - ncontrib_i}{\text{slope}_i}\right)$$

The **future contribution** is then simply

$$fcontrib_i = \text{scale}(\text{slope}_i \times horizon)$$

Z-Curve Functions



$$y = Z(x) = \begin{cases} \text{low} & \text{if } x \leq a \\ \text{low} + \frac{x-a}{b-a}(\text{high} - \text{low}) & \text{if } a < x < b \\ \text{high} & \text{if } b \leq x \end{cases}$$

Poisson Processes

In a Poisson process, the probability that a single event will occur during *any* very small interval of time is constant, whether other events have occurred recently or not. The average rate of occurrence, λ , determines that probability. The probability that n events will occur during an interval of length t is given by:

$$P_n(t) = \frac{e^{-\lambda t} (\lambda t)^n}{n!} \quad n = 0, 1, 2, 3, \dots$$

If the interval of time is always the same, the product $\mu = \lambda t$ can be used to restate this formula for the probabilities recursively as

$$\begin{aligned} P_0 &= e^{-\mu} \\ P_n &= P_{n-1} \cdot \frac{\mu}{n} \quad n = 1, 2, 3, \dots \end{aligned}$$

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