# Exploration of Soldier Morale Using Multi-Method Simulation Approach

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## ABSTRACT

Soldier morale is a complex social construct influenced by factors at multiple levels and integrates many research domains. Performance of soldiers can be influenced by morale, but the degree of this effect is difficult to assess and map back to strategic, operational, and/or tactical decisions based on current research approaches. Physiological and psychological factors related to low morale can lead to undesirable behaviors like suicides, substance abuse, and accidents. The current approach to measuring soldier morale is often based on a single point estimation limiting dynamic perspectives on this phenomenon. This may also impact similar exploratory studies - due to insufficient data for validation of model causalities. The simulation-based work found in the literature focuses on a single level of analysis and uses the System Dynamics method, which overly reduces scope and detail necessary for capturing related dependencies even if more data were available. This research seeks to explore, model, and simulate soldier morale at multiple levels of analysis. The developed sample case scenario pertains to US security efforts against insurgency in Afghanistan in 2007. The scenario includes representation of the patrol base operations serving as a platform for calibration and exploration of factors affecting soldier morale and its relationship with sample performance measures. The developed proof-of-concept simulation model was used for testing the effect of both size of patrol base and violence level on soldier morale. The model can serve as a platform for evaluation of decisions during surges and deployments that pertain to system structure, scheduling, and policies.

## ABOUT THE AUTHORS

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**Thomas W. Mastaglio** earned a Ph.D. degree in computer science from the University of Colorado in 1990 with an emphasis in artificial intelligence and human factors in computing systems. He retired from the US Army in 1981. Dr. Thomas W. Mastaglio has over 25 years developing and managing simulation technology spanning a portion of his military service as an Army Officer, and 20 years working in academia and industry. Dr. Mastaglio was the founding Executive Director of the Virginia Modeling, Analysis, and Simulation Center at Old Dominion University. He has served during his 40- plus year career as a leader in the modeling and simulation technical arena both in and out of uniform, as well as industry.

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## INTRODUCTION

Assuming a particular definition of soldier morale can have methodological implication on empirical and simulation based studies investigating this phenomenon. According to Leighton (1949), "morale is the capacity of a group of people to pull together persistently and consistently in pursuit of a common purpose". Perk (1951) called morale "…the barometer of the individual's and the community's capacity for suitable response to the call of duty and of the fortitude and tenacity displayed in the response" (p. 39). The American Heritage® Dictionary of the English Language (2009) defines morale as the state of the spirits of a person or a group as exhibited by confidence, cheerfulness, discipline, and willingness to perform assigned tasks. Sanderson (2003) characterized morale as a human dimension, a feeling, or a spiritual quality. Richardson (1978) introduced the list of variables that influence morale at three levels of analysis: 1) individual level: physical and mental factors; 2) group level: confidence in leaders, confidence in comrades, and responsibility for comrades in group, and; 3) unit level: spirit of unit. Before articulating our view of soldier morale, the following sections will introduce chosen empirical findings related to soldier morale as well as the concepts and simulation models found in literature.

### Individual Soldier Morale

Halverson (1995) pointed at operational environment, family separation, work issues, and policy issues as four major factors affecting soldier well-being during operations in Haiti. The basic needs reflected in large operational environments related to hygiene, sufficient rest (sleep) and relaxation as an important factor for maintaining the psychological and physical well-being of soldiers. For instance, many soldiers during deployment to Haiti indicated that having little free time hurt their morale. Bell, Schumm, Segal, and Rice (1996) have shown importance of information, leadership, and family support on individual soldier morale. For instance, a battalion newsletter, handbook, general information, telephone calls, and leader support had a statistically significant relationship with one third of the measures of individual soldier morale. Smith and Hagman (1996) have demonstrated influence of job type and job expectations on morale. Morale dropped considerably over the duration of the deployment because of misconceptions created during pre-deployment recruiting and training. Quester, Hattiangadi, Lee, and Shuford (2006) found that Marines with no deployment time in their first term of service had reenlistment rates 6 to 7 percentage points lower than Marines who deployed. Reed's (2000) findings indicate that for soldiers who reported either high or very high morale, as the number of their deployments increase their morale decreases approximately 26, 23, and 16 percent, respectively. These results may seem contradictory assuming that high morale correlates with probability to reenlist, but morale depends on many factors and it can change after deployment, or during reenlistment phase. Mael and Palmer (1996) illustrated how intensity of mission can change perception on importance of attributes needed by soldiers and leaders. For instance, combat motivation and tolerance for boredom were ranked 22nd and 1st for missions in Sinai respectively, while the same characteristics were ranked 1st and 16th for high intensity missions in Somalia and Bosnia.

There are differences in literature in regard to influence of morale on soldier performance. Bell et al. (1996) have demonstrated a relationship between soldier morale and marital satisfaction, and their influence on perceived performance. The effect between changes in marital satisfaction and morale and perceived performance was 0.78 and 0.77, respectively. The analysis of the relationship between performance and morale of recruits after the first, second, fourth, and sixth week of basic training at a company level conducted by Bessinger Jr (1974) resulted in a correlation of less than 30%. Siebold (1996) stated that morale has limited explanatory power concerning small unit dynamics. Job performance was not significantly correlated with unit dynamic variables except in the case where personnel were emotionally committed to the Army; motivated by the mission due to patriotism. On the other hand, job motivation and effectiveness of leadership explained 80% of the variance in morale at a late-stage during a peacekeeping mission in Sinai. According to Fontana and Rosenheck (1998) exposure to traumatic events is one of most important factors causing mental health problems. Wilk et al. (2010) reported that soldiers experienced an average of 17.2 combat experiences during Iraq deployment. The Mental Health Advisory Team (MHAT) (2013) reported a dose-dependent relationship between levels of combat and well-being indices. The most difficult time during deployment reported by multiple deplorers was the last 3 months of tour; contributors were event related (casualty, major operations) and the period immediately after rest and relaxation (R&R) (MHAT, 2006).

Combat commanders should understand the importance of soldier morale, and simulation tools could improve understanding of this phenomenon beyond classical research methods. The general question is how to research, understand, model, simulate, and make decisions that pertain to soldier morale at multiple levels of analysis, taking into account individual and group factors. Use of different modeling methods could be helpful to link and integrate morale at different levels of analysis. One of the goals for representing soldier(s) morale in a model is the opportunity to test performance indicators in relation to the level of their morale, providing insight into desirable and undesirable effects of decisions about force structure, scheduling, and policies within military forces.

## REPRESENTATION OF SOLDIER MORALE

### The State of the Art

Menninger (1988) identified a psychological pattern called the “morale curve” which consisted of four major crisis periods: arrival, engagement, acceptance and re-entry. The curve is consistent with the model of morale developed by Stafford-Clark (1949). The design of this model was based on the evolution of flight crew morale during their tours in World War II. Menninger (1988) has advocated a morale curve as general to any new life situation, with the timing of crisis duration dependent on duration of this new situation. The (MHAT) (2008) provides a soldier combat and well-being model adapted from Bliese and Castro (2003). This model includes risk factors such as combat exposure, deployment concerns, deployment length, multiple deployments, sleep deprivation, and protective factors (e.g. leadership, cohesion, mental support, rest and rehabilitation, training and marital support). A combination of risk and protective factors are considered in measuring the behavioral health status. MHAT reports provide statistical data useful for model development and validation, but single data points of individual morale throughout the deployment period limit insight into the dynamics associated with soldier morale.

Bross (2005) discussed implementation of soft factors based on definitions provided by the National Ground Intelligence Center (NGIC) as: amount of time officers and soldiers serve together, unit pride, similarity of view on risk for soldiers and leaders, unit discipline, tension within units, leader-subordinate loyalty, soldier-to-soldier loyalty, unit morale, and national support. Equation 1 represents behavioral soft factors ($SF_{Behavior}$) used to map weighted values of NGIC factors (N) along with unit ranking factor (R) and unit function (F) to five engagement behaviors: rate of direct fire, speed of maneuver, suppression of the rate of direct fire, suppression of the speed of maneuver, and unit breakpoints (Bross, 2005).

$$SF_{Behavior} = \Big(1 - \big(N_{\%} \cdot (1 - N)\big)\Big) \cdot \Big(1 - \big(R_{\%} \cdot (1 - R)\big)\Big) \cdot \Big(1 - \big(F_{\%} \cdot (1 - F)\big)\Big) \qquad (1)$$

The general conclusion of simulation experiments conducted by Bross (2005) was that the impact of soft factors including morale is evident. Artelli (2007) noticed that in the Bross’s (2005) work the values of morale factors did not change during simulation.

> “However, this test did not dynamically change these factors, but rather merely established that the model does depend on the factors. Additionally, these factors were not traced to specific events or actions conducted by friend or foe” (p. 82).

Artelli (2007) modeled soldier morale of the combatant and population at strategic levels as a part of the effort to investigate long term impacts of asymmetric conflict. The model included the following main elements: representations of asymmetric conflict, soldier morale, and public opinion. The model was calibrated within the context of the war in Iraq. Representation of asymmetric conflict and soldier morale sub-models are briefly introduced next. A System Dynamics (SD) model of the U.S. forces was used to represent *Blue* (*B*) and insurgents *Red* (*R*-insurgents) levels. Deployments and redeployments are modeled at the brigade and battalion levels. Attrition rates are determined with a version of Lanchester's Equations 2 and 3 provided by Bracken (1995) where $k$- is blue is the attrition coefficient, $c$ –is red attrition coefficient, $and\ d$- is Bracken's Tactical Parameter which can be used to account for defending force when equal to $d$, or attacking force when equal to $1/d$. The number of red and blue forces are described as $R$ and $B$ respectively.

$$\frac{dB}{dt} = c(d\ or\ 1/d)R^pB^q \qquad (2)$$

$$\frac{dR}{dt} = k(d\ or\ 1/d)B^qR^p \qquad (3)$$

The soldier morale sub-model takes as input the length of deployment (T), duration in theater (t), and coefficient for veteran status (v) indicating some initial deterioration of soldier morale due to previous deployments. Artelli (2007) fitted the curves of soldier morale provided by Stafford-Clark (1949) and Menninger (1988) to the equation based on the second order transient system responding to an impulse signal (Ogata, 1997, p. 159). As illustrated in Equation 4 $c(t)$ – is the time solution for the impulse response for $0 \leq \zeta \leq 1$ and $t \geq 0$, $\omega_n = \frac{\omega_d}{\sqrt{(1-\zeta^2)}}$ is a natural frequency, $\omega_d = \frac{2\pi}{TL}$ is damped natural frequency, $L$ is the coefficient for the percent of deployment, and $\zeta$ - is the damping ratio of the system.

$$c(t) = \frac{\omega_n}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t} sin\omega_n \sqrt{(1-\zeta^2)}\ \ t - v \quad (4)$$

The soldier morale sub-model was inserted into Equation 3 in place of Bracken's Tactical Parameter.

**Challenges to Represent Soldier Morale**

Artelli (2007) used a SD model to represent the situation in Iraq at a strategic level, with morale phenomenon represented at brigade and battalion levels. A question arises how to represent factors like soldier morale at a single level of analysis. Soldier morale could be considered unique to each soldier, but an individual level should also inform assessments at aggregated levels. The bottom up direction of inference is difficult, but may be necessary to facilitate more insight. For instance, veteran status for soldiers in a brigade can be different because some soldiers may be serving their first term, while others have already served one or more deployments. The scope of Artelli's (2007) model could also be expanded for factors at different levels that could affect individual soldier morale; for instance the population and family support of the mission, or morale boosting events at a group level. Artelli (2007) emphasized dynamic aspects of events and situations affecting a combatant's spirit within combat models, and pointed out that current models do not capture dynamics based on the actions within the model. He said that "…a higher fidelity operational or tactical model is able to provide inputs to this lower fidelity model" (pg. 5), indicating that his initial modeling efforts using an aggregated view can provide insight for the future model expansions that should accounts for more detail. On the other hand, the computational complexity as discussed by Brooks and Tobias (1996) can limit this modeling approach, which may be computationally expensive and difficult to trace when taking into account too many individual characteristics of soldiers. It should be noted, that experimentations conducted by Artelli (2007) showed a limited impact of morale on the $B/R$ ratio, which differs from experimentation conducted by (Bross, 2005). This points a need for a more thorough examination of soldier morale.

Soldier morale is a social phenomenon, which historically has been difficult to model (Artelli, 2007). This difficulty can be better understood when looking at Sun's (2006) hierarchy of analysis in social and cognitive science. The hierarchy includes; the sociological level (socio-cultural, social structure, interaction between agents etc.), the psychological level (individual experience, behaviors, performance, beliefs etc.), the componential level (cognitive agents in terms of components, intra-agent processes etc.), and the physiological level (biological, neuroscience etc.). All the levels may be important when matching them with morale factors provided by Richardson (1978), but inclusion of all factors in a simulation model that spans all levels is very difficult to achieve. McGinnis (2005) points out the challenge of conceptual integration of organizational views as well as technical challenges related to software engineering in achieving effective organizational simulations. The proper balance between fidelity, computational and simulation architecture complexity should allow for a simulation tool to be useful for research as well serving as a decision making tool. The current state-of-the-art in representing constructs such as morale using M&S techniques fits the Carson and John (2004, p. 18) statement: "For a simulation analyst, simulation is both an art and a science" (p. 18). Nonetheless, the M&S community should strive to improve this situation and make "a science" part more valid and "the art" part more credible. The problem of accurate representation and validation of soldier morale relates to its dynamics, but there is insufficient longitudinal data for validation of proposed concepts. Advanced studies of the human brain should in the future allow for closing this gap. Currently, research combined with longitudinal qualitative and quantitative data gathering and different analytical and simulation methods could provide means to get better insight into morale dynamics. A model validation based on the current theoretical assumptions, and without more accurate data would be at best partial (e.g. data obtained from MHAT reports during OIF and OEF usually provide a single data-year point of morale).

### Theoretical Basis

Before developing a conceptual model and the simulation model, it is necessary to define soldier morale and discuss theoretical assumptions in the context of the model. Based on reviewed literature we define soldier morale as the interdependence of both a state of human body and mind that drive the level of soldier confidence, cheerfulness, discipline, and motivation to perform assigned tasks. State of the human body is related to physical processes and the state of mind is influenced by all three levels of consciousness (Kaku, 2013). According to space-time theory of consciousness Level 1 pertains to factors related to the space, Level 2 takes additionally into account relations with others (social aspects), and finally, Level 3 adds abilities to mentally project past into the future (mental simulations) (Kaku, 2013). Based on this theory, soldier morale can be affected by its physiological and social feedback loops and additionally soldier's mental simulations. The mental simulations related to soldier morale can be spurred by significant events as perceived by a soldier; for instance deployments, combat events, command events and contacts with family or friends. These events can produce both negative and positive physical and mental states and mental simulations that can add up with time. Time is an important factor in relation to understanding the dynamics of soldier morale. For instance, negative mental simulations based on experienced battle events can last for a long time as shown in the case of Post-Traumatic Stress Disorder (PTSD) patients. Menninger (1988) identified a psychological pattern called "morale curve" which consisted of four major crisis periods: arrival, engagement, acceptance and re-entry. During the initial crisis of arrival phase the physical states of soldiers are often good, but mental simulations of the possible consequences related to the upcoming challenges and time left on deployment produce implications related to risks of being injured or to die. This along with the burdens on the soldier body related to the environment and battle events cause a quick decrease of soldier morale to reach its lowest level during the crisis of engagement phase. After soldiers become more accustomed to the situation, their morale raises during the acceptance phase. The final re-entry phase is related to simulations of the end of the mission, which can have positive or negative effects on soldier morale, depending on the awaiting situation at home. Menninger (1988) has advocated that a morale curve can be generalized to any new life situation. This could be explained using space-time theory of consciousness. When a significant life altering event happens, humans initially recall and project this event into various future scenarios more often, which diminishes in frequency as the time passes. If many events occur in close time intervals they compete for soldier consciousness, which all may affect morale to a higher or lesser degree.

## MULTI-METHOD APPROACH TO SOLDIER MORALE

Balaban and Hester (2013) investigated the purpose for multi-method simulation. The analysis of relevant literature allowed attributing complementary nature of methods with data availability and usability, skills and preference of a modeler, stakeholder acceptability, expectation of unique insight, and diverse needs related to understanding, credibility, and validity as the main reasons for using a multi-method M&S approach. Artelli (2007) points at a need for a more detailed model, and that an additional method other than SD may be necessary.

> "The system dynamics framework provides a mechanism to incorporate elements of fourth generation operations. It can be used either directly or in concert with other modeling approaches to aid in analyzing courses of action, effects, and plans in asymmetrical or irregular warfare" (pg. 223).

### Purpose of Simulation Model

The purpose of the simulation model is to advance knowledge about soldier morale and explore representation approaches. In future work the model can be extended to represent unit cohesion and perception about leaders as factors of soldier morale, these are themselves a complex social phenomenon and are deserving of a separate paper. A sample case scenario described next is created to provide a more tangible operational environment for exploration.

Operating from patrol bases (PB) in Afghanistan can be often more effective in counterinsurgency (COIN) operations by limiting threat related to improvised explosive devices (IED) during a commute from forward operations bases (FOB) to further located areas of operations (AO) (Army, 2008). A PB must be able to defend itself and accomplish mission objectives (Army, 2007). The size of force in a PB should be adequate to the level of insurgency in the area; they may be comprised of companies, platoons or squads. Inadequate sizing of a PB force can have a negative impact on a population's perception of security and trust in the military forces protection against insurgents (Army, 2008). Moreover, the size of PB affects operational capabilities. This in turn can impact soldier morale. Many commanders indicate that force of company size is the minimum. This way one platoon can protect the base, while two or three additional platoons can support missions outside of the PB. Operations from the PB pose additional challenges; undeveloped facilities affect living conditions and diminish combat power because of internal risks (Army, 2008). Soldiers are often frustrated because of the prolonged low quality of life, affecting their morale. The representation of the PB operations can serve as a platform for exploration of the events and factors affecting soldier morale and the relationship with performance measures. The following section investigates components of a simulation model and methods to represent relationships between the size of the PB and soldier morale. The developed simulation model is used to explore possible ties between soldier morale and psychological problems related to deployment. The modeling process itself can provide insight into initial conditions and the dynamic processes influencing morale during deployment. The idea behind the model is to create an experimental platform that can help investigate dynamic dependencies between input factors, soldier morale, and output measures of interest.

## Conceptual Model

The proposed conceptual model consists of factors affecting morale during deployment as shown in Figure 1. At the lowest level, soldier morale is influenced by a factor that represents basic needs, such as sleep, hygiene, food, shelter conditions and health (Halverson, 1995). Significant events related to combat events most often have negative effects on morale, but they can boost morale, especially if they significantly add to a perception of mission success. Moreover, battle exposures improve soldiers' combat skills. Lengthy deployments have mostly negative influence on soldier morale, but this can vary depending on individual perceptions about deployment (Hosek, Kavanagh, & Miller, 2006). Moreover, extensions of deployment length before and during deployment have an additional negative impact on morale. Deployment related financial incentives can increase morale, but can inversely decrease morale if none are provided, but were expected. A number of deployments generally have a negative effect on morale, but the steepest descent is seen during a second deployment. Personal time off, rest and relaxation (R&R) after a major event, and mid-tour leave time have a positive influence on morale, but soldiers indicated a quick drop of morale right after the return to PB (MHAT, 2008). Contact of soldiers with family or relatives can have mixed effect on morale. Perceived importance of the mission positively affects soldier morale. Both, support from the population of the country of origin and mission success have positive influence on perceived importance of the mission. The insurgency level has a negative influence on mission success and increases the combat level. The size of the local base has a positive influence on sleep time and amount of soldiers' personal time. The output consists of performance measures of interest, which can be related to depression, work performance, suicide, unethical behaviors, or substance abuse (MHAT, 2008).

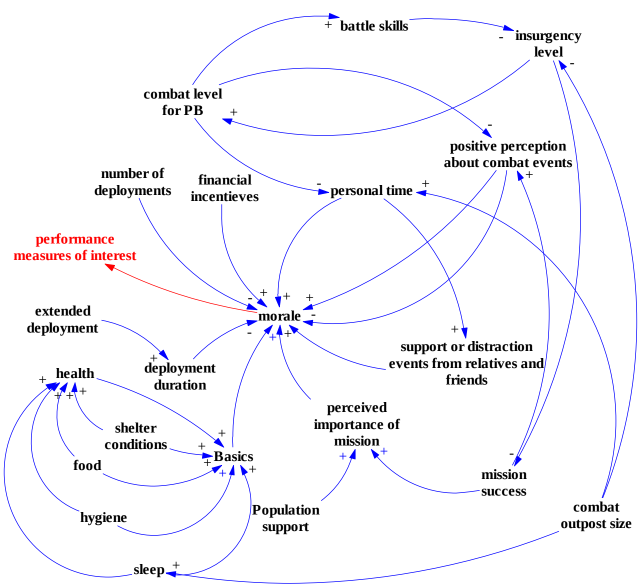


**Figure 1. Conceptual model of soldier morale**

### Identified Major Components and Subcomponents

The static view of the model is presented as a simplified UML class diagram shown in Figure 2. The hierarchical structure provides a way to organize the model at different levels of analysis. Different methods such as Agent-Based Modeling (ABM), Discrete Event Simulation (DES), and SD and Control Theory (CT) equations have unique features identified to implement the model. PB is the main component embedding all the other components. Because the Agent-Based Modeling (ABM) method with object orientation can be used to embed components (composition) at different levels, it is used for individual objects such PB, platoons, soldiers, and significant events. This provides an overarching structure of the model. The duality of platoons and soldiers are shown as aggregations. They both exist as agents within their respective parent ABM agents and DES entities within PB processes. Both process and individual views are necessary for those components to fulfil the dependencies of the conceptual model. For instance, groupings of soldiers within PB operations are developed using process blocks of Discrete Event Simulation (DES) to represent dependencies of rotations between duties, off-time, and mission-time. This in turn allows for capturing soldier individual times spent during each of the PB processes. Figure 3 displays main parts at PB level.

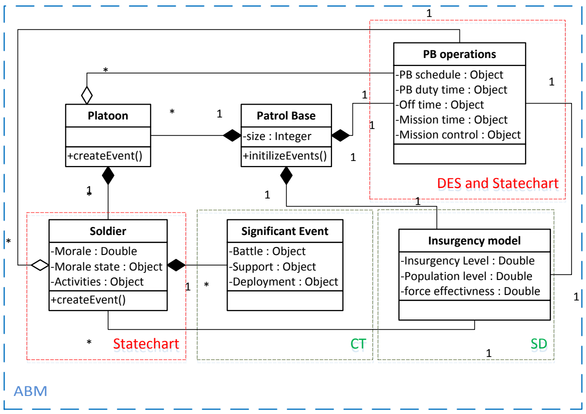


**Figure. 2 Major components mapped with methods used**

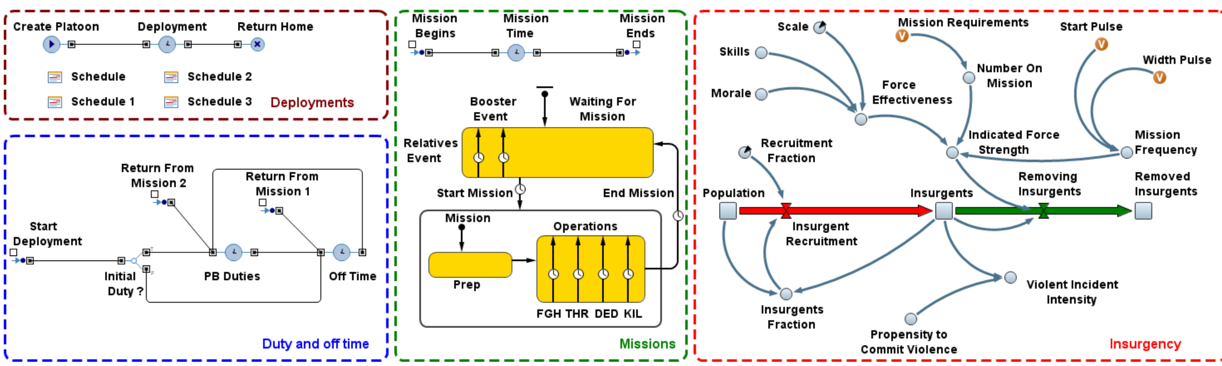


**Figure. 3 Components within patrol base level**

The frequency of missions depends on an insurgency level in the area, calculated based on a simplified model of insurgency by Sokolowski and Banks (2009). Each model of a soldier tracks their mission, duty, sleep, and personal times based on their PB activities. At the lowest level, significant events can occur within each soldier model. The events are represented using extended CT equations provided by Artelli, Deckro, Zalewski, Leach, and Perry (2010). Representing each soldier as an agent embeds their significant events and multiple individual factors to calculate individual morale, which is discussed next.

### Modification of Soldier Morale Equation

Based on both space-time theory of consciousness (Kaku, 2013) and theoretical implications proposed by Menninger (1988) about generalizability of significant events, it is assumed that effects of mental simulations of significant events on morale diminish in intensity with the time. The model represents soldier morale during deployment at individual level. The soldier morale ($SM$) variable is divided into three weighted categories shown in Equation 5.

$$SM = Dep_E w_1 + Bat_E w_2 + Aux_E w_3 \qquad (5)$$

The first category consists of effect of the overarching deployment event $(Dep_E)$. The second category is conceptualized to capture effects of combat related events $(Bat_E)$. The last category $(Aux_E)$ consists of auxiliary conditions and events such as basic needs, personal time off, contacts with relatives and friends during deployment, financial incentives, and mission importance. The overall weights are adjusted to add up to one in the case where no battle event is present.

The soldier morale model developed by Artelli (2007) was extended as shown in Equation 6. Different parameter values allow shaping the curve to desire effect of different events.

$$Event(t) = S_s + \frac{\omega_n}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n(t-t_0+t_{set})} sin\omega_n\sqrt{(1-\zeta^2)}\;\;(t-t_0+t_{set})\, S_c \quad (6)$$

A steady state for the event $S_s$ defines the level at which the curve settles after a transient period; $\omega_n = \frac{\omega_d}{\sqrt{(1-\zeta^2)}}$ is a natural frequency; $\omega_d = \frac{2\pi}{TN}$ is damped natural frequency; $T$ is a period [days] length of switching cycle(s) of the event; $N$ allows for manipulation of the length of total period; $t$ is the effect duration spurred by the event; $t_0$ is a simulation time at the initialization; $t_{set}$ is the time added to arrive at desirable initial conditions for the event (e.g. max, min, middle point); and $S_c$ is a scale parameter used to adjust response to 0-1 boundaries.

Initial conditions of $Dep_E$ event were set as follows. The values of zeta $(\zeta)$ and $N$ were initialized at 0.2 and 0.7 respectively as provided by (Artelli, 2007). Except for both an initial length of deployment $(T_{init})$ and a veteran status $(V_s)$, used in different part of the equation, initialization of soldier morale for the deployment event uses a normalized parameter( $I_k$) as shown in Equation 7.

$$I_k = \; Norm(B_{init\_k}w_1 \; + \; R_{init\_k}w_2 + \; M_{init\_k}w_3 + C_{init\_k}w_5 \; + \; F_{init\_k}w_6) \quad (7)$$

The aggregated variable $I_k$ is embedded in the Equation 6 using a $t_{set}$ parameter (via lookup Table 1) based on a yearlong deployment. This effectively shifts the curve along its time frame resulting in different initial values. It consists of the initial satisfaction with basic needs $(B_{init})$; the initial support from relatives and friends $(R_{init})$, the initial perceived importance of the mission $(M_{init})$, self-confidence in skills related to training and mental toughness accrued before deployment $(C_{init})$, the effect of financial incentives $(F_{init})$, and weights of importance for each of the variables $(w_{1-6})$.

**Table 1. Lookup table for setting value of initial morale**

| initial morale | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 0.98 |
|---|---|---|---|---|---|---|---|---|
| $x_{I_k}$ | 1.56 | 1.745 | 1.935 | 2.125 | 2.35 | 2.64 | 3.1 | 4.35 |

The value of veteran status $(V_s)$ relates to the number of deployments. It is subtracted from the steady state variable $S_s = middle\ point - V_s$. The value of the $middle\ point$ can be understood as soldier's general attitude and it is used during calibration of the model. Artelli (2007) decreased initial morale 3 percent after each deployment because he used aggregated values. Reed (2000) analyzed the effect of multiple deployment on morale showing that the percent of soldiers who reported either high or very high morale decreased to approximately 26% after one deployment, 23% after two, and 16% after three or more deployments. A Mental Health Advisory Team (MHAT, 2013) report provides values for individual morale being high or very high after first, second, and third deployment as 29%, 18.4%, and 20.3% respectively. The unquestionable drop is observable during the second deployment. Because of inconsistency in empirical research, the middle values were assumed. In the developed model $V_s$ is decreased between 6 and 12 percent for the second and later term deployed soldiers using a uniform distribution. The proportion of the first and consecutive deployees within the population was approximated using MHAT (2008) data.

The effects of battle events on morale are captured as $Bat_E$ factor. Four categories of combat experiences were considered based on MHAT (2011): death and injury of others $(e1)$, fighting $(e2)$, threat of death or injury to oneself $(e3)$, and killing others $(e4)$. The average value is used to assess current effect of combat events in the Equation 9.

$$Bat_E w_2 = Avg\;(\,e1, e2, e3, e4) \qquad (9)$$

Each new fighting experience increases skill level and confidence of a soldier. The initial frequencies of combat events are based on 2007 data from operations in Afghanistan provided by MHAT (2011). This report estimates

13.6 total experiences per soldier, and provides percentages of each of four events reported at least once. These data are used to calibrate frequency of battle events as a function of intensity of violent incidents, which influence mission frequency, and affects frequency of battle events. Each soldier can be on the mission, stay on duty, or has time off (including sleep time). A soldier's internal state chart tracks times of each activity, which are used then within the morale equation.

During the simulation run, the value of variables within $Aux_E$ (shown in Equation 8) fluctuate depending on the changes related to satisfaction with basic needs ($B_{dep}$), general support from relatives and friends ($R_{dep}$), perceived importance of the mission ($M_{dep}$), financial incentives ($F_{dep}$), personal time ($P_{dep}$), average impact from command support events ($M_E$) and contacts with relatives events ($P_E$).

$$Aux_E = B_{dep}w_1 + R_{dep}w_2 + M_{dep}w_3 + F_{dep}w_4 + P_{dep}w_5 + Avg(M_E + P_E)\,w_6 \qquad (8)$$

Frequency of $M_E$ and $P_E$ events depend on personal time of soldier and base status in relation to planned or ongoing missions.

**Limitations, Assumptions, and Model Calibration**

The major limitation of the model pertains to missing Level 2 of consciousness (Kaku, 2013), which takes into account relations of a soldier with others (social aspects). The inclusion of this level could allow representing effects of cohesion and leadership on morale. Future exploration and addition of these phenomena to the model is discussed briefly in the final section of this paper. Moreover, attrition of PB forces related to combat events was not modeled, but can be added in the future.

Because no research has been found that quantifies effects of significant events on soldier morale, the values of $Bat_E$ and $Aux_E$ events were implemented using Equation 6 with parameters assumed, as shown in Table 2. Veteran status ($V_s$) equals zero and $N$ equals one for all the above events. Death and threat events are assumed to always have a negative effect on morale. Fighting and killing have either a negative or positive influence on morale, depending on mission success. Mission success depends on the number of removed insurgents. Family events can also have either a positive or negative effect on morale. The size of the error between morale value (21.7% reporting high or very high morale) provided by MHAT (2008) and a simulated value was used for calibration. The population of soldiers in the MHAT (2008) report is divided into four categories: soldiers with less than 6 months in theater, between 6 and 12 moths, above 12 months, and unknown time in theater. In order to provide a soldier morale data point as a calibration point, it is assumed that on an average the data were collected at month 3, 9, 12, and randomly between 1 and 12 months for each of the categories, respectively. A value of $middle\ point$ and weights $w_1, w_2,\ and\ w_3$ from Equation 5 were used as parameters for the model calibration. The size of platoon and base minimum duty is assumed to be 20 and 6 soldiers, respectively. It should be emphasized that because there is no longitudinal data within single deployment available this calibration result is only one of the possible feasible scenarios. Moreover, all weights and factors not discussed thus far were approximated by authors; hence the results from the following experiments should be interpreted cautiously. In the future the model could be further calibrated across multiple years and use more calibration parameters.

**Table. 2 Parameters for various events**

| Combat factors | Zeta (ζ) | Significance (T) [days] | Steady state (Ss) | Scale (Sc) | Initial point (tset) |
|---|---|---|---|---|---|
| Death | uniform (0.35,0.45) | 60 | uniform (0.35, 0.45) | 120 | 0.52 |
| Fighting | lookup table (mission success) | 20 | lookup table (mission success) | 120 | 0.52 |
| Threat | uniform (0.4,0.45) | 60 | uniform (0.35, 0.5) | 180 | 0.52 |
| Killing | lookup table (mission success) | 20 | lookup table (mission success) | 120 | 0.52 |
| Command support events | 0.6 | 5 | 0.7 | uniform (20, 45) | 0.6 |
| Contact with relatives events | 0.6 | 3 | uniform (0.4, 0.7) | uniform (20, 30) | 0.6 |

**Experiments and Results**

Consecutive occurrences of two deployments were simulated to demonstrate the importance of insurgency characteristic on soldier morale. The size of the mission team was adjusted using a uniform discrete distribution based on number of available soldiers minus duty size and rest rotation set to two. Thirty simulation replications were run for each scenario. Most of the measures are self-explanatory, although time spent in low and very low morale is a more specific measure. MHAT (2008) estimated that 17% of soldiers screened were due to some kind of psychological problems (e.g. depression, generalized anxiety, and acute stress). This was used to calculate time value as 17 % percent below the maximum value for the PB population as a measure for comparison between scenarios. Sample results for six scenarios are shown in Table 3. Figure 4 displays scenario 5, where two platoons face 40 violent insurgents (propensity to violence equals 0.05). The sample graphical results include time series percent of average number of soldier in each of morale state (from very low to very high), average morale curve, and average time spent for various activities measured as hours per day. The first two platoons deployed did the majority of the effort to clear the area which can be observed as decreasing mission time. The following next two platoons were not needed but were scheduled. A single platoon at most would have been sufficient. The importance of size of force on effectiveness and morale is visible but results indicate no single pattern between factors. This indicates the difficulty analyzing individual morale at an aggregated level. The number of removed insurgents depends also on their propensity to violence, and drives perceived mission importance. It positively affects morale when a sufficient number of soldiers can handle demand (see difference between cases 4 and 5 during first deployment for time spent in low or very low morale). It should be noticed that there is little control over propensity of violence; technically, if insurgents do not come forward, perceived mission effectiveness may be low with the same effort, and frequency of violent acts do not change over a long period unless more soldiers are available. Other basic needs like sleep and personal time can add to the overall value of morale, but are difficult to discern at the aggregated view. Combat events can affect soldier morale, but beyond certain thresholds they do not affect morale significantly. This result is related to using the average to calculate influence of battle events on morale, and it needs further investigation. Effects of battle events may require scaling using lookup table based on interviews with soldiers.

**Table. 3 Results from 6 sample simulation scenarios**

| | Case scenario | Initial number of insurgents | Propensity to violence | Number of platoons | Number of removed insurgents | Percent morale high or very high | Sleep time (h/d) | Personal time (h/d) | Mission time (h/d) | Duty time (h/d) | Number of combat events | Number of aux events | Time spent in low or very low morale (h) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| first deployment batch | 1 | 20 | 0.005 | 1 | 5.5 | 19.4 | 8.5 | 6.9 | 0.7 | 6.8 | 13.3 | 23.0 | 252.6 |
| | 2 | 20 | 0.005 | 2 | 10.5 | 27.8 | 10.1 | 9.0 | 0.7 | 3.4 | 23.0 | 61.4 | 240.0 |
| | 3 | 20 | 0.005 | 3 | 13.8 | 24.1 | 10.7 | 9.7 | 0.6 | 2.3 | 29.0 | 100.7 | 164.8 |
| | 4 | 40 | 0.050 | 1 | 38.1 | 26.4 | 6.9 | 4.5 | 4.5 | 6.8 | 85.8 | 6.0 | 271.8 |
| | 5 | 40 | 0.050 | 2 | 42.5 | 35.2 | 9.2 | 7.7 | 2.7 | 3.4 | 99.8 | 38.8 | 89.9 |
| | 6 | 80 | 0.050 | 3 | 82.3 | 39.7 | 9.0 | 7.7 | 3.5 | 2.2 | 186.4 | 56.9 | 109.5 |
| second deployment batch | 1 | 19.2 | 0.005 | 1 | 4.6 | 8.1 | 8.5 | 7.0 | 0.7 | 6.8 | 12.4 | 23.6 | 1520.8 |
| | 2 | 13.4 | 0.005 | 2 | 6.5 | 19.8 | 10.2 | 9.1 | 0.5 | 3.4 | 18.6 | 65.0 | 1279.0 |
| | 3 | 9.7 | 0.005 | 3 | 6.5 | 22.3 | 10.8 | 9.9 | 0.3 | 2.3 | 17.0 | 114.6 | 980.1 |
| | 4 | 7.4 | 0.050 | 1 | 7.8 | 36.6 | 8.4 | 6.8 | 1.0 | 6.8 | 19.5 | 21.9 | 94.2 |
| | 5 | 0.2 | 0.050 | 2 | 0.2 | 36.3 | 10.4 | 9.4 | 0.0 | 3.4 | 1.3 | 78.2 | 194.2 |
| | 6 | 0.0 | 0.050 | 3 | 0.0 | 37.9 | 10.6 | 9.7 | 0.0 | 2.2 | 0.3 | 125.0 | 199.0 |

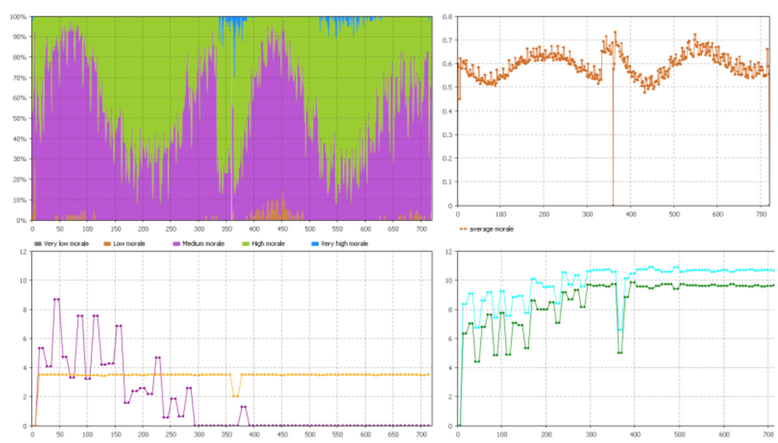

**Figure 4. Graphical results for scenario 5 (single run)**

**FUTURE EXTENSIONS**

The work presented in this paper is an initial step toward a more holistic representation of soldier morale. As extension to the model additional elements like soldier attrition, unit cohesion and leadership should be considered.

The effect of the relations between soldiers and leaders to characterize unit cohesion and leadership seem especially desirable. For instance Bartone and Adler (1999) have considered unit cohesion a factor of morale. Siebold (1996) defined cohesion "…as the degree to which the forces of social control, internal and external to individual group members, maintain a pattern of relationships among the members which allows the group to accomplish its mission" (p. 240). It is measured in terms of the affective and instrumental bonds, but also considers relationships between peers, leaders and their subordinates, group members and unit as a whole. Manning (1991) indicated that time spent together, especially with a common experience of stressful events related to combat, and effective communication with leaders about the mission, contribute to the unit cohesion. Bartone and Kirkland (1991) stated that based on supporting evidence from the field, cohesion and morale appeared to be substantially influenced by small unit leaders. Bartone, Marlowe, Gifford, and Wright (1992) found that cohesion (in relation to degree of combat exposure) affected a soldier's psychological health and well-being. For instance, combat stress was reduced when unit cohesion was high. They tracked unit cohesion along key sources of stress before, during, and after deployment and evaluated the impact of these sources on soldier morale and cohesion. Bartone and Adler (1999) have shown that cohesion generally increases over time, forming an inverted U-shaped curve. Social Network Analysis (SNA) method should be investigated to represent cohesion and leadership effects within the unit, which could indicate dependencies between soldier morale, unit cohesion, and leadership (Gockel & Werth, 2010; Zacharias, MacMillan, & Van Hemel, 2008). The future goal of the model would be to test configurations of input variables that allow avoiding undesirable behaviors and health problems while reinforcing positive behaviors through observance of soldier morale dynamics (Sriram, Rodriguez-Fernandez, & Doyle III, 2012; Wang, Glover, Rhodes, & Nightingale, 2013; Wilk et al., 2010).

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