# Simulation of Non-Combatant Population Movement in the Battlespace

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## ABSTRACT

The risk of adversaries instigating mass human migration, refugee flows and crowd formations in the battlespace[1] requires mitigation because unexpected population movements can adversely impact the United States and partners' freedom of operations abroad. As well, Information operations and physical events initiated by operations in an area may result in population activity patterns (second and third order effects/events). Even relatively small gatherings of non-combatants, especially at urban choke points can have repercussions impacting military operations which rely on predictable traffic flow on roads and infrastructure. Simulation in the field of Pattern of Life Analytics (PoLA) is critically important to the military because it may lead to improvements in predicting patterns of movement and other behaviors that are realistic, reliable, and repeatable among non-military populations. There is insufficient modeling of the political, economic and social conditions within the operational environment (OE) and their effects on combatants and noncombatants. Meanwhile, emerging connected device tracking technologies provide rich new data sources required to assess ongoing patterns of life activity levels (traffic patterns, work, shopping, pedestrian flow, refugee movement, crowd gatherings and so on). This paper describes a technique for representing migration of a civilian population in a way that is amenable to computation (i.e., simulation). The model firmly rooted in social science principles for: a) establishing a baseline of population location data, b) calculating populace mood changes based upon Political, Military, Economic, Social, Infrastructure, Information, Physical Environment, and Time (PMESII-PT) interventions, and c) forecasting timing and size of refugee flows and direction of their movements to, d) further model their external migration in Athena. As a result, the military decision makers can understand PMESII-PT impacts of non-combatant population movement in the battlespace. Lessons learned from this work could be used to simulate and predict non-combatant movement and identify potential impacts in the OE.

## ABOUT THE AUTHORS

Tony Cerri is the Data Science and Modeling and Simulation Director for the TRADOC G-2. He is responsible for the integration of technologies to facilitate OE representation. Previous assignments include leading the JS J7's Joint Operating Systems Environment, leading the Experiment Engineering Division for USJFCOM J9 and serving as M&S Branch Chief for USJFCOM J9. Tony is a graduate of the United States Military Academy. He earned master's degrees from Central Michigan University in Administration and from the Florida Institute of Technology in Management. His military awards include the Legion of Merit and the Bronze Star.

[1] We use the term battlespace vice the more doctrinally correct operational environment (**OE)** term throughout this paper to mirror operational commander usage and directly address the associated physical geometry considerations of C2 in joint operations areas (JOA) and area of operations (AO).

Nicole Laster, Ph.D. is lead social scientist for the U.S. Army, TRADOC G-20 Global Cultural Knowledge Network (GCKN) at Fort Leavenworth, Kansas. Dr. Laster supports TRADOC G-2 as an applied social scientist with a focus on delivering systematic and defensible research to the Army's warfighter to the point of decision. Her academic research centers around influence messaging and its implications on thought and behavior. She holds a B.A in Communication Studies from The University of Kansas and Ph.D. in Organizational Communication from The University of Texas at Austin. Her research can be found in the International Journal of Business Communication, Business Communication Quarterly, and Western Journal of Communication.

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Steven B. Hall, Ph.D. is a Research Professor at the Naval Postgraduate School. He earned a Ph.D. in Cognitive and Social Science from the University of California, Irvine in 1983 with an emphasis on generative multi-agent multi-scale modeling. His current research focuses include: enhancing our understanding of the foundations of "social resiliency"; understanding the impact of sensemaking crises on identity dynamics; and the effective engagement of crowds using non-lethal weapons to maximize perceived State legitimacy. He has published 35+ papers in technical journals and proceedings.

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## BACKGROUND

The concept described in this paper involves the use of socio-economic factors -- political, military, economic, social, infrastructure, information, physical environment, and time (PMESII-PT) – in a deterministic PMESII-PT-related simulation tool called *Athena*, and in conjunction with established social science principles in a new way. Athena is used to: a) baseline initial status quo population location data; b) calculate populace satisfaction / mood based upon PMESII-PT interventions; and c) forecast the timing and size of refugee flows and the direction of their movements. This data is then used to determine the effects on battle outcomes. Modeling population migration in Athena will enable a deeper understanding of PMESII-PT impacts on non-combatant population movement in the battlespace. Lessons learned from this work will enable military planners to simulate and predict non-combatant movement and to identify potential impacts in the OE. Military planners will improve their means to diagnose, identify, and assess indirect strategies, as well as develop response options against associated types of adversary challenges in the increasingly complex OE. The concept also describes how social science principles can be integrated with an existing deterministic model. This paper includes recent proof-of principle demonstrations of the capability to conduct planning for non-combatant population movement in the battlespace during a campaign-level, near-peer, warfighting scenario exercise.

## OPERATIONAL PROBLEM

Allied Joint Doctrine for Civil-Military Cooperation does not address the planning for non-combatant population movement in the battlespace in sufficient detail. It merely states that, “the presence of significant numbers of non-combatants remains one of the defining characteristics of operations in an urban area. The military commander may have her/his freedom of action reduced by legal constraint. The attitude of the local populace, whether hostile, compliant or supportive, will be an important factor in planning an appropriately scaled and resourced force structure. The consequences of not dealing with these hazards appropriately could be immense for allied forces and non-combatants alike.” (AJD, CMC, 1).

Joint forces must incorporate non-combatant population movement in the battlespace into planned training and exercises (CJCS, 2013). According to Army Doctrine Reference Publication (ADRP) 3-0, *Operations*, “Commanders are to consider minimizing civilian interference with operations and minimizing the impact of military operations on the population”. Not considering population dynamics in the equation could significantly impact operations, and not accounting for population movement could restrict freedom of maneuver. Conversely, anticipating or influencing population movements can positively impact Joint operations and outcomes.

## Introduction

Army guidance states the "Army must incorporate realistic conditions, including robust Opposing Force (OPFOR)/Red Cell into exercises, in order to develop capabilities and Tactics, Techniques, and Procedures (TTPs), as well as incorporate lessons learned from operating in denied or manipulated environments" (CJCS, 2014, 4). . The incorporation of the results for the proof-of-principle described in this paper will better enable commanders to understand and visualize the impacts of non-combatant population movement across the battlespace. It combines both qualitative and quantitative analytics in a notional near-peer wargame setting to show impacts of an adversary massing cyber and information to create conditions required to initiate population movement in the battlespace.

## Multi-Domain Training includes Non-Combatant Movement in the OE

Joint and Army training is needed across the land and cyberspace domains, as well as the information environment, which enables military planners to simulate and predict non-combatant movement to identify potential impacts in the OE. The Joint Force must compete and win in every domain: air, land, sea, space, and cyberspace, as well as in the information environment. According to the *Chairman's Joint Training Guidance*, "Adversaries continue to innovate and adapt in these domains to erode U.S. advantages…improving joint training approaches and exercise scenarios for contested domains and emphasizing cross-domain synergy throughout joint training programs will develop a Joint Force that can think and operate in this multi-domain environment". (CJCSN 3500.01, *2017-2020 Chairman's Joint Training Guidance*, 1/12/2017)

In a recent near-peer simulation exercise, a notional opponent ("red force") leveraged non-combatant movements in the OE in order to gain strategic, operational and tactical military advantage. This paper shows how notional adversary forces in control of a city in the battlespace not only have a psychological or political advantage, but can leverage this to significantly affect the battle outcomes. Specifically, this paper shows how a numerically smaller opponent Red force can gain advantage over a much larger opponent ("blue force") by massing multi-domain effects of cyber and IO focused on an urban non-combatant population to create enough chaos to cause non-combatant population movement in the battlespace to work in the their favor.

In this exercise, Red forces' strategic disruption of essential services created an artificial and exploitable condition. By waging complex local cyber-attacks on key infrastructure—in particular, the electric power grid and water distribution systems, even the most loyal civilian groups became quickly stressed and easily dissatisfied with elected officials. Eventually, cyber-initiated local brownouts, a pre-planned disinformation campaign, combined with a limited flow of essential services (food, water, medicine, etc.) led to significant refugee populations. These non-combatants were influenced by Red forces in such a way so as to clog lines of communication (LOCs) and significantly slow the Blue force freedom of movement. This paper further describes how Red forces in a notional scenario successfully massed cyber-attacks combined with IO (e.g. "fake news", social media, etc.) to delay Blue forces and thereby buy critical time to assess the Blue force objectives and enable Red force reinforcement. In short, Red forces used the age-old principle of mass[2] (in this case, massing of cyber and information messaging operations) against non-combatants to delay Blue forces.

## Models of Migration - Non-Combatant Population Movement in the Battlespace - Patterns of Life Analytics

This paper describes a proven technique for representing the patterns of life – specifically predictable population migrations of non-combatant civilians in a way that is amenable to computation (i.e., simulation):

> Migration modeling has a long history. For decades, the literature was dominated by the gravity model, which posits that the volume of migration between two locations increases with population sizes in each location

[2] Joint Publication 3-0, Joint Operations (17 January 2017) defines **mass** as follows: 1. The purpose of mass is to concentrate the effects of combat power at the most advantageous place and time to produce decisive results. 2. In order to achieve mass, appropriate joint force capabilities are integrated and synchronized where they will have a decisive effect in a short period of time. Mass often must be sustained to have the desired effect. Massing effects of combat power, rather than concentrating forces, can enable even numerically inferior forces to produce decisive results and minimize human losses and waste of resources

> and decreases with geographical distance between the locations. The spatial interaction models that evolved from the gravity model incorporated additional determinants of migration and historical migration patterns that were considered to have long-term effects. The aim of migration modelling has been and still is to explain observed migration flows and to predict migration flows at a future point in time. (Klabunde and Wilkins)

Population migration modeling is a subset of the more generalized construct we call Pattern of Life Analytics (PoLA). PoLA is important because it may lead to improvements in simulating observable patterns of behavior that are realistic, reliable, and repeatable among non-military populations. These patterns, or interruptions of the same, could then serve as intelligence indicators to analysts, commanders and staffs. Population migration effects within the larger field of PoLA could include movement and the absence of movement to points of interest (going to places of worship, marketplace, school, work, flash mobs, refugee flows, etc.). For example, if vehicle traffic on a major urban street was completely absent it could indicate an impending attack.

This paper highlights the importance of PoLA to deterrence, shaping and stability operations and the importance of integrating new forms of commercial intelligence, surveillance, and reconnaissance (ISR) as a means for the Joint Force to observe and analyze patterns of life. (See Figure 1) Some would argue that the ability for simulations to portray such behaviors could be considered, in some cases, to be equally as important as the representation of kinetic effects. The approach enlightens the notional force commander concerning which strategies and tactics are most and the least successful. It addresses non-combatant population movement in the battlespace and provides a realistic exercise inject for Blue forces to overcome

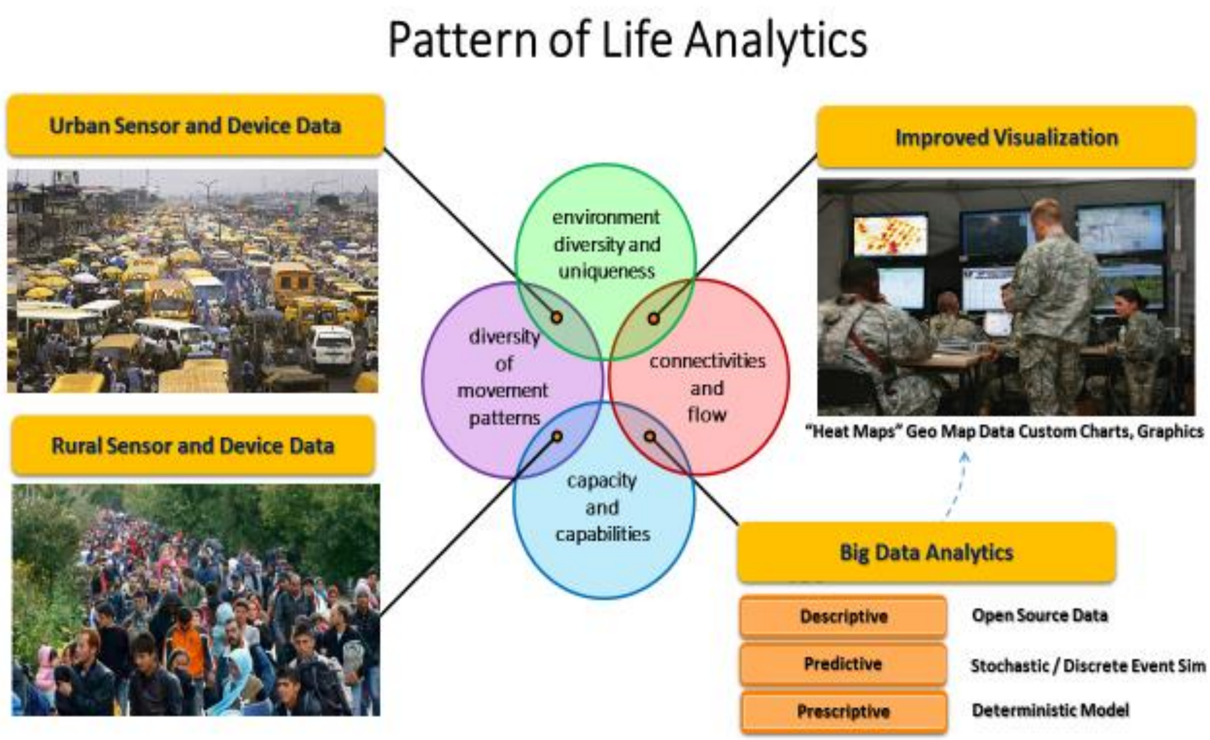


**Figure 1: PoLA**

## OVERALL ANALYTIC FRAMEWORK AND APPROACH

### Framework

The overarching simulation of non-combatant population movement in the battlespace concept was implemented into a warfighting scenario, which for the first time integrated what can be called the Migratory Tipping Point Model (MTPM) in conjunction with Athena's computational modeling processes. MTPM (described more fully later in this paper) supports access, replication, and delivery of population migration effects in an OE-relevant context.

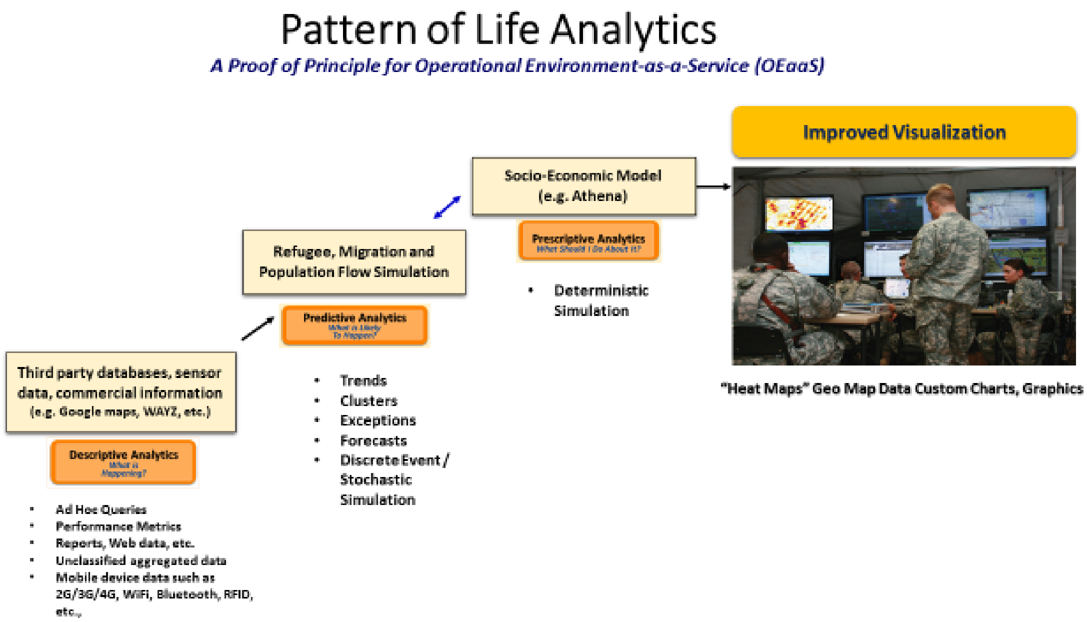


**Figure 2: PoLA Process**

The notional warfighting exercise provided the conditions, circumstances, and influences in which the implementation of populace/refugee movement both affected and shaped the decisions of the commander. This proof-of-principle is imbedded in a technology-assisted analytic framework. TRADOC G-27 employed this approach as an early foray into experimenting with PoLA and as a "big data" tool to understand and visualize the OE. All three areas of big data analytics -- descriptive analytics (discrete event simulation and data mining), predictive analytics (forecasting), and prescriptive analytics (optimization and simulation) -- were included in the concept. (See Figure 2) The analytic results produced insights and improved the understanding for commanders and staffs during the warfighting exercise. The approach provided a richer contextual picture of the impacts of population movements, as well as insights into the sensitivity of an adversary massing cyber and information operations to influence local populace movement in a complex, congested, and competitive OE.

The Athena Support Team (AST) supported the G-27's Threat Emulation Force (TEFOR), which served as the Red forces during the wargame. The MTPM was paired with the Athena Simulation to enable an assessment of the second- and third-order effects of a combined information and cyber-attack occurring in a notional warfighting scenario. This provided a realistic means to emulate cyber/information effects upon the PMESII-PT variables. Participants noted that this approach may have an unexpected benefit of improving the understanding of the Army's operational design methodology and the military decision-making process (MDMP). This exercise demonstrated whether a concept such as MPTM, used in conjunction with Athena, could provide an improved means to leverage PoLA in the OE. The overarching issue was whether PoLA using MPTM would improve the ability of the commander and the staff to identify, understand, and predict potential intended and unintended consequences of simultaneous cyber and IO. It successfully showed how the various response strategies and tactics may have to be coordinated to effectively respond to these notional adversary challenges in PoLA of population movement.

### Step 1: Descriptive Analytics Used for Characterizing the PMESII-PT Variables

#### *Baseline Initial Status Quo Population PMESII-PT Data*

The AST conducted historical research into each of the PMESII-PT variables in the scenario area, watching especially for those that might be affected by adversarial cyber and IO. These variables and their interrelatedness determine the nature of an OE and how it might affect or be affected by an operation. The OE data sources typically include, but are not limited to:

- Strategic partners (e.g., NATO, UN, World Bank, international community)
- Interagency partners (e.g., DoS/USAID, DoJ, CIA, etc.)

- Multinational partners (e.g., host nation governments)
- Non-governmental organizations (e.g., Doctors Without Borders, International Red Cross) Industry and Academia

### *Baseline Initial Status Quo Population Location Data*

According to Novak, "[r]efugees are by definition mobile, and their mobile devices have already been proven as life-saving whether they are calling the coast guard from a raft in the Mediterranean or facilitating a reunion with lost family members. Mobile apps have the potential to revolutionize aid resource allocation and relocation support in the humanitarian sector. The possibilities are endless." (NOVAK, 2015)

New data sources associated with population movement are becoming commonplace. According to Qadir, "with the advances in technology (in terms of computing, communications, and the ability to process, and analyze big data), our ability to respond to disasters is at an inflection point. There is great optimism that big data tools can be leveraged to process large amounts of crisis-related data (in the form of user generated data in addition to traditional humanitarian data) to provide an insight into the fast-changing situation and help drive an effective disaster response." (Qadir, J, 2016)

Commercial sources of tracking non-combatant mobile devices are increasingly important because commanders want to know the real-time situation on the ground with respect to movements of population and vehicles (e.g. refugees, crowds, disaster evacuations, and/or traffic jams). While free or paid Google Maps/Earth, Waze and government/commercial third party traffic visualization and location tracking services are sometimes available, none of these commercial and third party sources on their own provides data that are timely, accurate and complete enough to meet the Army's need. Unfortunately, urban settings present special location tracking challenges due to global positioning system (GPS) errors from urban masking of satellites, cell towers, etc.

Therefore current analytic approaches are unable to meet a commander's needs. Commanders are, instead, faced with situations and a lack of analytics that risk lives, property and the accomplishment of the mission. Using commercially available mobile device tracking from Military commanders overseas could be provided an unclassified population/traffic/migration overlay for her/his situation map that identifies the presence (or absence) of massing protesters, flash mobs, or traffic jams affecting freedom of movement on LOCs.

### Step 2: Predictive Analytics –Forecasting Using the Migratory Tipping Point Model (MTPM)

The next step for the team was to forecast the timing, size, and direction of movement of refugee flows in order to prepare for the final step of modeling population movement in the battlespace in Athena. The framework for these decisions are informed by the Migratory Tipping Point Model (MTPM) which is grounded in traditional migration factors, Maslow's motivational theory, and Value Congruence

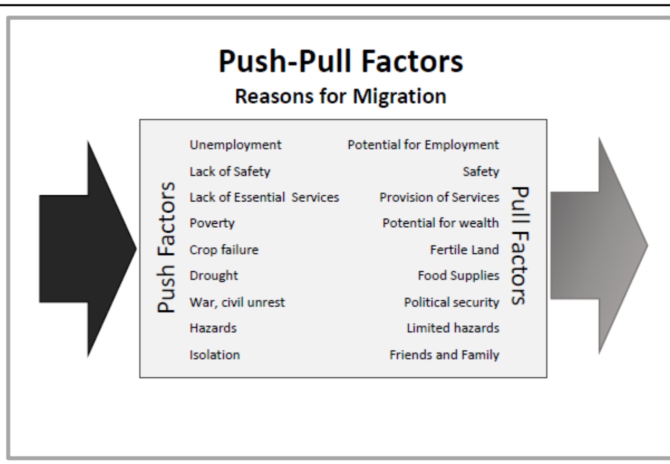


**Figure 3: Push Pull Factors for Migration**

Traditional migration theory suggests the convergence of "push" (of diminishing opportunities) and "pull" (of new opportunities) factors in explaining migration. Many use the push/pull framework to explain the factors that hold as well as compel migration (e.g., Lee, E. S., 1966; Portes, A., 2010), Radu, D., 2008; Zelinsky, 1971)). People often migrate as a result of a simple cost-benefit analysis where the reasons for remaining are less tenable than the reasons for leaving. However, traditional theories do not account for the complexity of technological influences to create and complicate an artificial reality as well as the psychology of migration.

In situations involving insidious motivations for influencing migration (i.e., Red forces desire to create calculated and timely non-combatant movement), technology can be used as a potential weapon. In these cases, technology may be used as a forcing function for disrupting essential services as well as a means to intensify emotions, accelerating motivations and baiting action. The Migratory Tipping Point Model (MTPM) begins by setting conditions against the backdrop of traditional push/pull factors (Laster & Johnson, 2017). According to Abraham Maslow's motivational theory, human action is motivated by several levels of human needs. Maslow's theory explains in part the migration flows between regions. Movement from one place to another influences migrants utility through three various ways. First, through change in the ability to obtain clean water and food caused by different quality of life satisfaction levels in each location. Second, through changes in utility connected with individual's safety needs (difference in perceived threats from ongoing fighting). And finally, "through disarrangement of individuals' social networks. (2005, Reichlová)

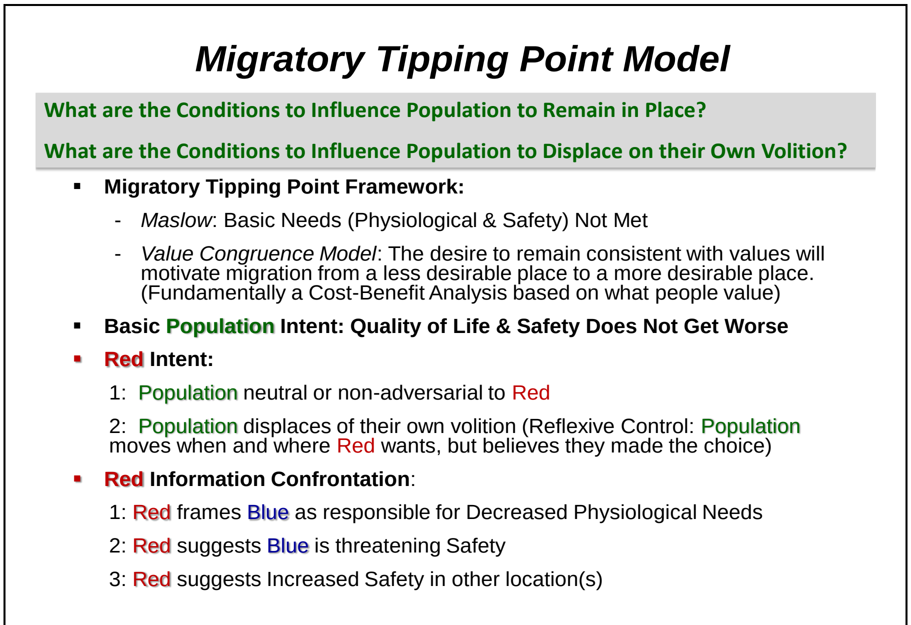


**Figure 4: Notional Adversary's Migratory Tipping Point Model (MPTM)**

It is the fusion of these motivations that create a desire that triggers the migration impulse or ideation. When combined with deceptive messaging the outcome is a desired effect for the adversary. For Blue forces population migration presents a complicated hazard. This allows Red forces to amass multi-domain effects and leverage non-combatant movements in the OE to gain strategic, operational and tactical military advantage.

Micro-simulation and agent-based modeling are already being used jointly in several migration models. According to Klabunde, "there is a need for more applications of agent-based modeling (ABM) in migration research. Many migration-related research questions can be tackled extremely well with agent-based modeling. Among these questions are the following: How do changes in social norms related to marriage and fertility affect the timing of migration? Do the size, direction, and timing of migration flows depend on whether the decision-making happens on the individual or on the household level? What proportion of migrant location decisions can be explained by social effects, and what proportion is attributable to other factors? What changes if the social influence is age-specific? Is the theory of planned behavior a plausible decision theory for the migration decision? How will demographic change alter the composition of the migrant population? How will labor markets be affected? Migration is a trending topic in demographic research, and its importance continues to increase (Bijak et al. 2014). Agent-based modeling of migration decision-making is just

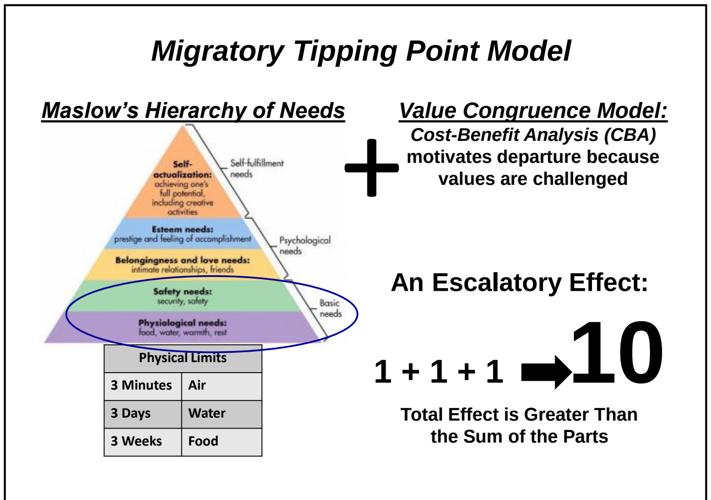


**Figure 5: Creating an Escalation Effect through Simultaneous Information Operations**

starting to develop. The initial attempts are promising and are paving the way for a new generation of models that can predict who will migrate, why they will migrate, and when they will migrate." (Klabunde 2014).

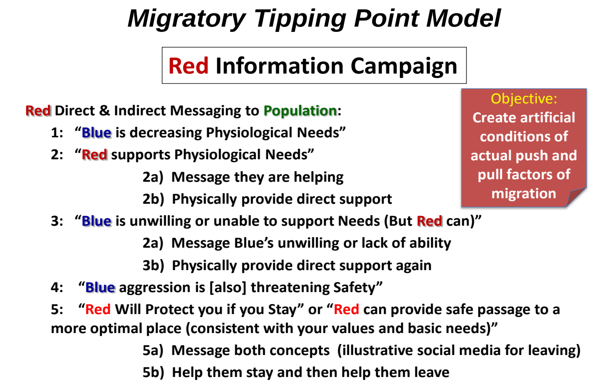


**Figure 6. Notional Adversary Messaging Campaign**

Value congruence, meanwhile, gets at the similarity between an individual's values and the values prevailing in the social environment. Thus, it serves as an important lure to engage traditional pull factors. In this notional wargame, we looked at socio-demographic groups with which to compare values to determine what groups in a commuting distance would be candidates to host any population migration from the affected battlespace urban area. The study team felt Congruence Theory has even more influence in this scenario than the Theory of Planned Behavior (TBP). TPB predicts an individual's intention to engage in a behavior at a specific time and place. According to Ajzen, "it posits that individual behavior is driven by behavior intentions, where behavior intentions are a function of three determinants: an individual's attitude toward behavior, subjective norms, and perceived behavioral control (Ajzen, 1991). However, Congruence Theory asserts that action is motivated by a desire to reduce incongruence and to return to homeostasis. In our situation, balance is achieved by the rejoining of others who share the same values and beliefs (i.e., socio-cultural), regardless of physical location. The desire to be around people of like mind becomes of central importance. Refugees are thus propelled by the reconstitution of the regional sociopolitical order spurred by emerging powers with growing economic and ideological influence combined with the existence of diaspora communities and networks that stretch back to their homelands (in other words "a mobile or transient homophily." So, congruence theory suggests refugees will be willing to move if they are able to identify states with significant diaspora communities whose influence encompass their communities of origin. Predictive analytics provides the ability to extract meaningful information from vast amounts of data allowing us to identify patterns and trends, make connections between seemingly unrelated data sets, and predict future outcomes.


**Figure 7. Athena Modeling Sectors**

Athena sector modeling shown in Figure 7 provided understanding, visualization, and conduct of course of action (COAs) analyses. Athena-based analyses typically involve wargames, and in this case involved a computer assisted wargame (CAW). The utility of Athena is to quantify the criteria that were used to evaluate the COAs. Based upon the MTPM results at the warfighting exercise, notional massed effects from cyber-attacks and IO were modeled in Athena. The reduction of infrastructure capabilities—in this case, electric power, banking, and telecommunications sectors of the host nation country by its adversaries—was then implemented in Athena. These all had profound impacts on civilian perceptions of availability of water and food. The effects of these attacks were blamed by Red forces on the Blue forces through the implementation of a concomitant IO campaign. Subject matter experts gauged that the disruption of essential services, such as water, food and electricity, would have escalatory effects on the populace, although the full impact would be hard to measure as almost all critical infrastructure sectors are connected to the energy sector. Locally affected markets slowed to a halt as commercial utilities and financial institutions struggled to operate with only limited access to the Internet. Frustration with the local government and state legitimacy emerged, resulting in a loss of popular confidence. The scenario used in Athena was based upon historical cyber-attacks conducted in Europe over the last 10 years.

Athena's modeling of the impact of cyber-attacks, as characterized by MTPM, helped Red force decision makers anticipate the likely consequences, both planned and unplanned, of various threat courses of action. Athena's modeling was comprehensive and anticipated the second- and third-order effects upon competing noncombatant groups and actors as well as potential reactions. This effort allowed our study team to explore the nature of the capabilities – conceptual, procedural and physical – necessary for navigating the human dimension in PoLA population movement in the battlespace.

**RESULTS**

In this notional campaign scenario, the Red forces massed complex IO and coordinated cyber-attacks (using MTPM and an escalation effect) in a locally contested urban area which succeeded in creating problems with food and water distribution, banking, transportation, and economic infrastructures. A simultaneous IO campaign by the Red forces attributed these cyber-attacks to the Blue forces. In Athena, these tactics resulted in quantitative mood changes among hundreds of thousands of local civilians. The Athena simulation calculates mood (satisfaction) in terms of four factors—namely, quality of life, safety, autonomy, and culture—and found that in these circumstances there was extreme civilian frustration with their local and national governments.

Economic impacts in local areas were substantial as markets failed due to lack of information processing and transaction capabilities. Complex local cyber-attacks on key infrastructure—in particular, the electric power grid (this was a wintertime scenario)—stressed the most loyal civilian groups' satisfaction with their elected officials. Eventually, the local brownouts and limited flow of goods and services (Maslow effects) led to the formation of refugee populations being encouraged by "fake news" to travel in the direction of Blue forces (Value Congruence) to get to safety. This forced population movement clogged roads and significantly slowed the Blue forces' freedom of movement. The results demonstrated that the Red forces had successfully used IO and cyber-attacks not only to delay their enemies and buy time to assess the Blue forces' intent and objectives, but gain time for additional Red force personnel and materiel to arrive. Cyber-attacks by Red forces but blamed on others led to decreasing popular support and confidence in the local government. Beleaguered host nation governments eventually lost enough influence for Athena to calculate that influence and support had tipped now in the favor of the Red forces.

The following describes the Athena impacts based on each of the elements of PMESII-PT. These impacts created the escalatory effect which ultimately led to non-combatant population movement in the battlespace.

- Political: Cyber-attacks against "soft" commercial infrastructure attributed by "fake news" to Blue forces reduced political leaders' popular support. Cyber-attacks included: destroying, disrupting, or taking control of targets; protests and retaliatory actions; espionage.
- Military: Cyber-attacks coupled with "fake news" slowed the momentum of Blue forces and allowed time for reinforcement of Red forces.
- Economic: Cyber-attacks combined with information messaging impacted individual and group behaviors related to producing, distributing, and consuming resources. The Red forces used a sophisticated "botnet" attack such as was launched in 2007 upon the Estonian Government and commercial websites causing a Distributed Denial of Service Attacks (DDoS). A significant host of computers worldwide were used to conduct that attack, resulting in the complete shutdown of the cyber infrastructure. The Estonian government blamed Russian hackers for this attack; however, the Russian government denied involvement (Gandhi, 2012).
- Social: Cyber-attacks against the commercial economy and infrastructure attributed to Blue force actions and synchronized with information messaging led to reduction in support from all the local civilian groups as well as affected several areas of satisfaction, but most importantly feelings of quality of life and safety. These actions strained and adversely affected relationships between civilian groups and actors. This is notionally shown in Figure 8.

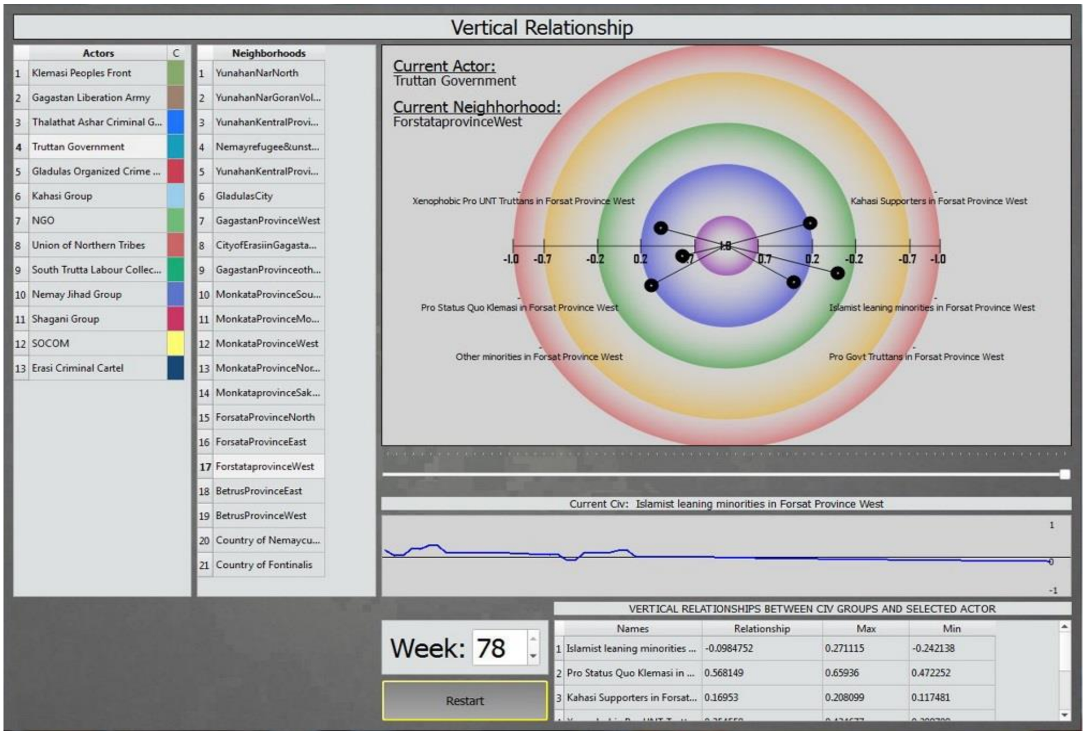


**Figure 8. Notional Results: Changes in Relationships**

- <u>Information</u>: Cyber-attacks affected e-Government and commercial systems that collect, process, disseminate, and/or act on information. This included all radio/TV and internet-based media. Cyber-attacks were carried out to enable the use of cyberspace to spread propaganda, attack websites, and steal money to fund activities or to plan and coordinate physical-world crime (Gandhi, 2012). Each of these events was modeled in Athena. The future OE will be even more wired to cyberspace and further sensitized to its content; adversary messaging may need to be analyzed and countered in near-real time. As a hypothetical example, if Red force messaging attributed civilian casualties to host-nation or Blue forces, imagery and eyewitness documentation (or refutation) of these incidents might be needed within minutes to forestall the formation of flash mobs by otherwise uninvolved civilians (TRADOC, 2012).
- <u>Infrastructure</u>: Cyber-attacks affected the composition of basic facilities, services, and installations needed for the effective functioning of a community or society. Local populations will be reliant by 2025 on an *Internet of Things* environment for all aspects of transportation, media, banking, and day-to-day economic activity. "Critical military communications and logistics systems, along with civilian financial and infrastructure networks, are now dependent on their supporting information systems, leaving them more and more exposed to crippling cyber-attacks" (TRADOC, 2012, 49). Consequences along the dimensions of financial, information, and physical losses are all the more tangible because of a cyber-attack. Physical loss in most instances occurs when the cyber world is tightly integrated with the physical world, as in the case of systems that control the distribution of power, gas, water, sewage, oil, and other critical services.
- <u>Physical Environment</u>: Cyber-attacks during winter weather conditions in this area of operations favored Red operations.
- <u>Time</u>: Cyber-attacks against civilian infrastructure as calculated in Athena and subsequently attributed to the Blue forces caused significant discontent and refugee flows, which provided the Red forces time to assess Blue actions and reinforce themselves.

## DISCUSSION

The integration of descriptive, predictive, and prescriptive analytics in a big data analytics approach coupled with insight visualization tools provided a significant value-added for the Red forces. This use of MTPM together with Athena may carry forward into future Army Warfighting Assessments. It offered the wargame commanders a new means for looking at massing of cyberspace operations and information messaging to create an escalatory effect on the will of the civilian populace. It facilitated an improved understanding, visualization, and insight into Pattern of Life operations and their impact on:

- Red force TTPs
- Blue force TTPs
- Country/region/operational domain data
- Best practices and lessons learned regarding simulation of non-combatant population movement in the Battlespace

The MTPM effects approach, when paired with the Athena simulation, enables important new insights when assessing the second- and third-order PMESII-PT effects in pattern of life particularly refugee migration in the battlespace. With the ability to predict trends in people escaping conflict, we can enable real-time military operations and overall effectiveness.

## SUMMARY AND CONCLUSION

The authors have described an initial approach toward using descriptive, predictive, and prescriptive analytics for improving Army operational design and MDMP assessment and planning processes. The Athena simulation, when used in conjunction with MTPM:

- Highlighted the PMESII-PT effects (both offensive and defensive) of pattern of life and allowed commanders and staffs to make informed decisions that maximized their effectiveness in a combined, campaign, near-peer, warfighting exercise.
- Provided a prototype of the pattern of life simulation design.
- Simulated for a training audience a variety of possible cyber-attacks (e.g., DDoS attacks, viruses, hacking, etc.) combined with information messaging to add realistic effects which allowed role-players to attack and react as appropriate.
- Provided the G-27 M&S Branch an opportunity to test a precursor to big data analytics for OE visualization, understanding, and advanced insights.
- Combined descriptive, predictive, and prescriptive analytics in such a way to provide a richer contextual understanding of the OE.
- Provided an innovative fusing of data by the MTPM and Athena simulation, which increased the ability to understand the intended and unintended consequences of cyberspace interventions. (Note: The results of this effort may lead to enhancements which can be synchronized with ongoing analytic requirements for potential integration into current and future Army Mission Command Systems).
- Provided a viable candidate capable of filling several identified gaps with regard to modeling human domain operations.
- Showed the utility of integrating results of migratory forecasting to provide a second layer of analysis. This may be applicable to other areas such as population follow models, etc.
- Addressed potential Essential Elements of Analysis (EEA) related to future OE interventions. For example:
  - How can the Army improve multi-domain operations within the context of a future 2025 combined campaign near-peer warfighting exercise?
  - What is the optimal way in a major future 2025 Scenario to mass cyber and information messaging in a non-combatant context to support Unified Land Operations (ULO) and deliver the PMESII-PT effects required by commanders at all echelons?

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