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Population Migration Decision-Making

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ABSTRACT

The risk of mass human migration, refugee flows and crowd formations in the battlespace, regardless of whether adversary instigated or as an effect of force-on-force activity, requires mitigation since unexpected population movement can adversely impact the United States and its partnering operations abroad. Even relatively small gatherings of noncombatants, especially at urban choke points, can negatively impact military operations which may rely on smooth traffic flow and open logistical routes. There is a significant gap in modeling of the representation of the political, economic and social conditions within the operational environment (OE) and their effects on combatants and noncombatants. The Headquarters, Department of the Army (HQDA) Army Studies Program funded the Naval Postgraduate School (NPS) to work in 2019 and early 2020 with TRADOC G-2 Modeling and Simulation Office to conduct a study titled, "Methodology for Predicting Noncombatant Population Movement in the Battlespace" to proof-of-concept model for population migration to simulate and predict noncombatant movement and identify potential 2nd and 3rd order impacts in the OE. The study led to the integrated use of the NPS agent-based model, Social Resiliency Model, (SoReM[1]) together with the Army's Athena[2] Simulation and has provided unique insights to OE characterization, risk assessment, synchronization, and course of action development. The lessons learned while using SoReM, to provide anticipatory analytics to the deterministic model, Athena, in order to assess noncombatant population migration in the battlespace, have furthered the Army's knowledge of modeling of noncombatant population migrations and tipping points. As future man-made and natural situations occur in an area being modeled, military planners will have a better understanding of the potential impacts of noncombatant population movement in the battlespace. Lessons learned from this work will also enable commanders to better simulate and predict noncombatant movement and identify potential impacts of noncombatant movement in the OE.

[1] SoReM - Social Resiliency Model. SoReM is the Naval postgraduate School's multi-scale, multi-agent social identity dynamics model that is used variably to both describe the current social Identity dynamics model implementation and the design for how it should be enhanced and refined.
[2] The Athena Simulation is the Army's social-cultural modeling capability which supports a decision maker by providing both a framework to better understand complex PMESII-PT/DIME-based problems and a simulation for anticipating the long-term consequences of engagement choices across the totality of the operational environment.

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Dr. Steven B. Hall, is a recently retired 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 multiscale modeling. His current research foci include: enhancing our understanding of the foundations of 'social resiliency'; understanding the impact of sense making 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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Dr. Matthew Zefferman is an Assistant Professor at the Naval Postgraduate School. (Ph.D. Ecology, Univ. of California, Davis, 2013) and uses analytical and computational models and ethnographic fieldwork to investigate culture and institutions for cooperation and conflict. After earning degrees in engineering and management at Cornell University, he served six years as an active duty Air Force officer. After earning his PhD in Ecology from UC Davis, he had postdoctoral appointments at the National Institute for Mathematical and Biological Synthesis, the Institute of Human Origins at Arizona State University, and as a Beall Defense Fellow at the Naval Postgraduate School.

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Dr. Jumanne K. Donahue has worked in support of U.S. Joint Forces Command and the U.S. Army Training and Doctrine Command G-27 Data Science, Models, Simulations directorate in various capacities. He was a cultural researcher and knowledge engineer on the First Person Cultural Trainer simulation developed for DSMS by the University of Texas at Dallas. Mr. Donahue holds a PhD in Arts, Technology, and Emerging Communications from the University of Texas at Dallas. He also holds an MFA in Arts and Technology from UT Dallas and a BS in Computer Science from Texas A&M University College Station).

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INTRODUCTION

Population migration decision-making as described in this paper is based on a recently completed Army Studies Program study entitled, *"Methodology for Predicting Noncombatant Population Movement in the Battlespace"* henceforth known as the Study. This Study was selected by HQDA for FY19/20 funding based on the Army's need to improve its understanding of how to model noncombatant population migration to support Multi-domain operations (MDO). The attitude of the local populace, whether hostile, compliant or supportive, is an important factor in multi-domain battle planning. The consequences of not dealing with these hazards appropriately could be immense for allied forces and noncombatants alike. 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".

Completed on 1 April 2020, the Study was conducted by the Naval Postgraduate School (NPS) in Monterey, California under the auspices of Army Studies Program and TRADOC Studies Program Offices (HQDA ASPMO: NPS-19-400-1974FY19/20). The results of the Study were certified by the US Army and accepted by HQDA on 28 May 2020. NPS, in coordination with TRADOC G-2 Modeling and Simulation Office (MSO) examined various aspects of the military's capacity to rapidly respond to threats and opportunities at the scale in which they present themselves; this fits not only with creating MDO windows of advantage, but exploiting them.

HQDA G-8 Army Studies Program Management Office (ASPMO) served as the Study Funding Authority and the TRADOC Studies Program Office was designated the Study Sponsor while TRADOC G-2 MSO was designated the Sponsor Study Director. This paper describes the process, results and recommendations stemming from this Study. It will comment on the Study outcomes and deliverables received from NPS and provide key highlights and discuss potential implications of each.

NPS activities achieved the overall HQDA Study objective of determining a methodology to model the factors that influence human migration patterns so as to predictively anticipate them. The Study process and outcomes were on-

time and on-budget despite the onset of COVID-19[3] disruptions to normal work patterns and travel plans at the NPS in February and March 2020. The Study team leveraged the use of notional unclassified but complex scenarios available through the TRADOC G-2 MSO to demonstrate results of automating a tipping point model to provide anticipatory analytics for noncombatant population migration and crowd formations in the battlespace.

PROBLEM

The Army lacks a suitable noncombatant population migration model to inform understanding of the operational environment (OE) and Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, and Time (PMESII-PT) / Diplomatic, Information, Military, Economic (DIME) effects on combatants and noncombatants. The Army has no standardized noncombatant population migration model that could be manipulated during the run of a crisis, for use both in training or simulations, or for prediction and early warning.

Not considering population dynamics during MDO could significantly impact operations, while not accounting for population movement could restrict a commander's freedom of action as depicted in Figure 1. Conversely, anticipating or influencing population movements can positively impact Joint operations and outcomes.

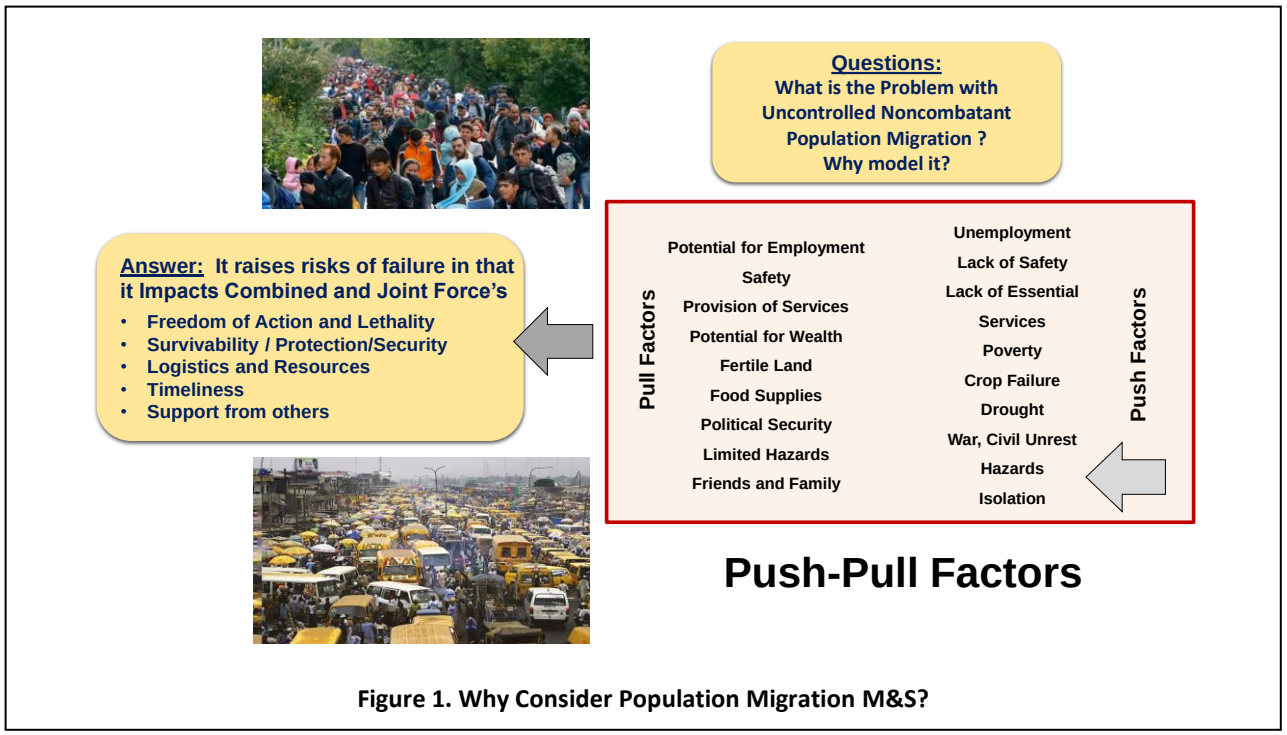

Figure 1. Why Consider Population Migration M&S?

Several issues present themselves including knowing where people will go, when they will begin to travel, and what would likely trigger their migration. There are strategic and tactical reasons to have a model that can reasonably identify how much of a given population would likely migrate. One can use existing road data, as most of the routes have not changed in centuries. Knowing the potential routes does not tell us which one will be selected; for that an analyst must look to a future model, and this problem underpins the rationale for this Study. According to NPS, "the essential problem with modeling migration is to limit the number of variables. Modeling requires parsimony and simplicity, since every additional variable can add complexity at the expense of realism." The NPS team attempted to boil migration down to essential variables that hold true across cultural and geographical contexts. Long-term research questions that were addressed in this Study included:

- How should civilian populations, for example Internally Displaced Persons (IDP) and refugees be modeled to improve situational awareness / situational understanding (SA/SU) within the area of operations (AO)?

[3] Coronavirus Disease - 2019

- What social science principles and theories should be used in a model to enable SA/SU within the AO?
- What techniques should be represented in a model to address SA/SU requirements for noncombatant population migration in the battlespace?
- What modeling is required to improve a decision makers understanding of Multi-Domain Battle with respect to the "human terrain" in the area?
- How will this model improve a commander's focus on the noncombatant constituents of politically fragile or failing identity groups within their AO?
- How does this model improve understanding of the operating environment, potential adversaries, and impacts of noncombatants on mobility and logistics?
- How will modeling noncombatant population flows help address the warfighting problem based on a complex modern battlefield, given the rate of change in terms of information access and decision calculus, and the role that non-traditional or proxy/hybrid actors play to shape operations, especially prior to armed conflict?

APPROACH

This Study is presented in this paper in three sections:

The first section describes the NPS work developing a formal model of human migratory behavior. Their focus was on determining what modeling was needed to represent population migration in the battlespace. The fundamental modeling approach NPS took was to decompose or unbundle factors that influence the formation of human migration events which involves predicting so-called, "tipping point" in migration decision-making, shown in Figure 2, and the patterns these follow so as to predictively anticipate them, particularly in the context of regional scenarios.

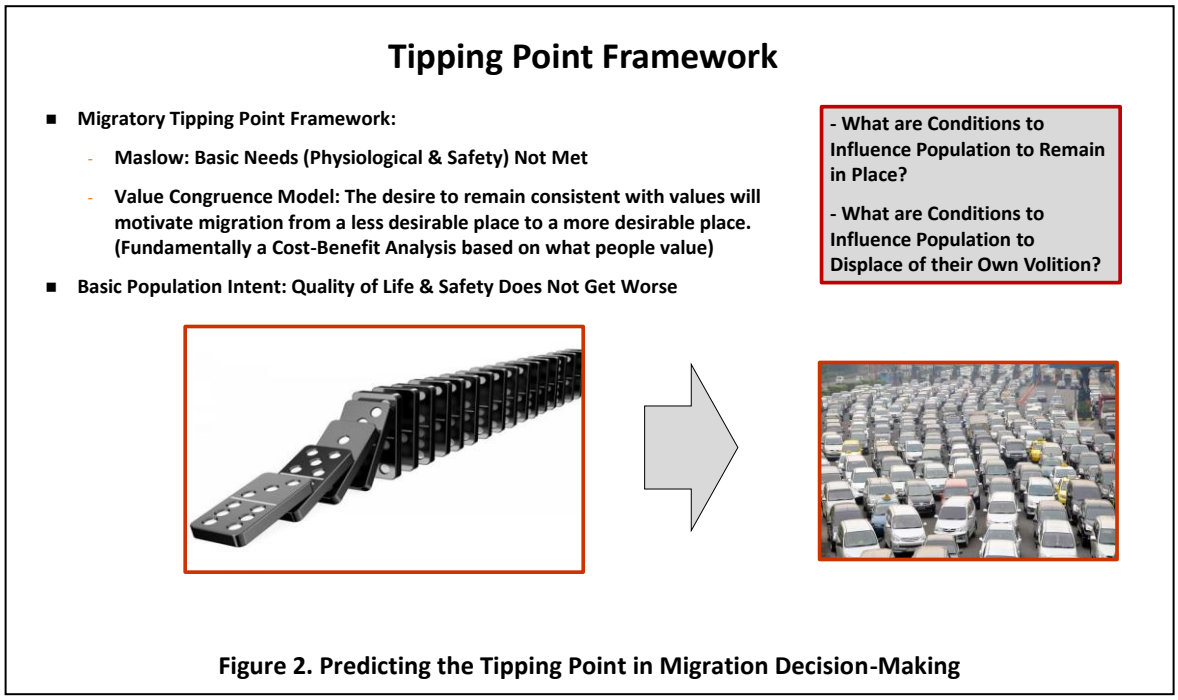

Figure 2. Predicting the Tipping Point in Migration Decision-Making

The second section of this paper summarizes the NPS efforts in learning more about a deterministic approach to modeling population migrations such as using a low-resolution aggregated model like the Army's Athena Simulation versus using its own high-fidelity stochastic agent-based model, SoReM.

The final section of this paper discusses recommended strategies for leveraging the Army's existing investment in Athena while moving toward a more capable model of the OE by integrating SoReM into the Army's PMESII-PT/DIME deterministic modeling environment. It will also discuss the development of a scripting methodology for

integrating the SoReM model outcomes into Athena to serve as an approach for providing a better model of human migratory behavior.

WHAT MODELING IS NEEDED?

Fundamentally, modeling mass migration is about understanding why people leave their homes. NPS discussed two types of migration models: one is population-level, which aggregates and is better for analyzing population movements on a country level, and the other utilizes agent-based modeling which does well at assessing high resolution detail. The one utilized depends on what level of analysis is desired – street and city level, or country. It is envisioned that each could be scaled up or down as necessary to meet analytic requirements. Figure 3 shows key factors for population migration.

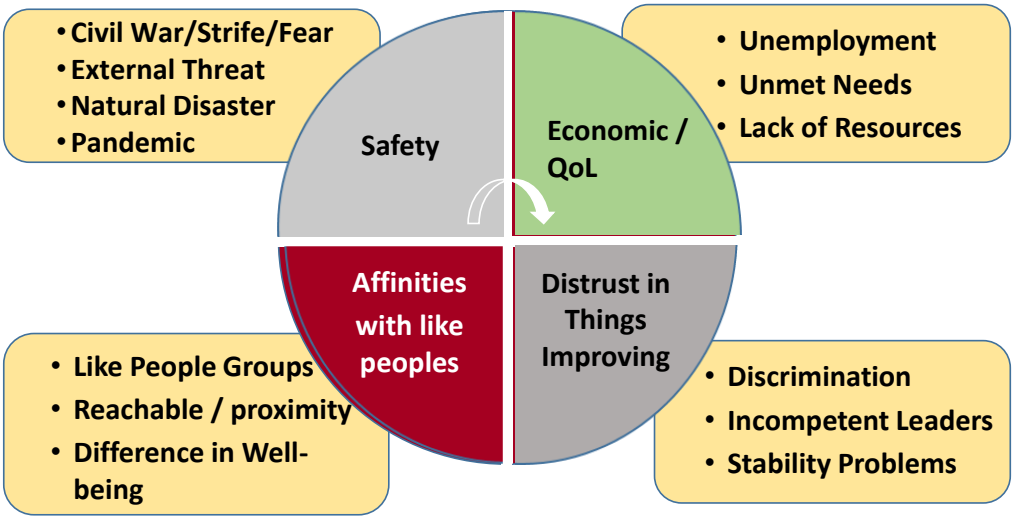

Figure 3. Key Factors in Population Migration Decision Modeling

Modeling *Why* People Leave

NPS based its modeling on two primary insights: first, migrants do think in terms of cost/benefit assessments, and secondly, they function as groups. Decisions to migrate are not linear, meaning that circumstances build on each other. Each violent or economic impact/threat is not taken individually, but cumulatively, amplifying a prior perception of being unsafe. Costs and benefits depend on the age of individuals and their economic circumstances, networks, and the possibilities for the migrants to safely establish themselves elsewhere. Professionals will have an easier time, as will those with family, friends, or networks in another country. From refugee data, it is known that the decision for masses to undertake the journey cascades from other people's decisions within their own significant identity group. To be more precise, the demographic group within a larger identity group is the one from which people take their cues. Families with young children (the demographic) will move when other families with young children in their identity group depart. Youth (another demographic) will migrate alone when other youth are also migrating. Different forms of violence generate diverse thresholds for migration and rates of departure. Internal violence generated by the government differs from foreign occupation, which differs from civil war. The messages people receive about the situation and how they perceive those messages (credible or not) alters the timeline. When determining the potential for migration, one must consider the information networks available and look at the messages being generated by people the migrating groups trust.

Modeling *Where* People Will Go

Where people migrate also depends on the practical ability to transit a particular route. A new migration model would include parameters that allow the user to input closed borders and the presence or absence of smugglers (guides) or border patrols. Migrants will generally choose the easiest and safest path, which NPS has algorithmically identified

through experiments using road data to determine the minimum costs of flight. Modeling can determine which route would be taken if some were closed, or alternatively, if opportunities opened farther afield. One could model such dynamics as they change, including new policy developments as inputs to the basic model.

Modeling *When* People Leave

NPS research indicated that in almost all emergency migration scenarios, not everyone leaves; some elderly, sick, or disabled are unable to leave, some individuals are unwilling to forsake their long-term homes. They fear the journey more than death or their attachment to their home/community is stronger than their fear – they take a, "This is my home and I will die in it" stance. Fear of uncertainty – of what the new place might hold – is also a key variable in delaying migration for the general public. Because of this, and due to the human trait of denial, there is a lag time between events and a migration. Until the reality becomes so clear one cannot avoid it, people will deny, postpone, and/or find ways to cope. The decision to depart depends on responsibilities which generally correspond to age. It also depends on possibilities, networks, financial ability to flee, which roughly corresponds to socioeconomic status. Other practical factors are important for determining whether people flee and where they flee to: geographical terrain, closed or open borders and whether smugglers exist to get people through. Decisions are generally made in groups – significant identity groups (SIG) – which are often described by networks, neighborhoods, or ethnic/religious beliefs. Migration also depends on the status of current livelihood, which will be discussed later when what could be a more complete model is introduced.

Learning from Study of Migration

One common misunderstanding about migration is the excessive focus on violence. The definition of 'refugee' is based on violence and persecution; however, people migrate *en masse* when they experience a sudden change in their situation, which includes both violence and economics. There are triggering events and background causes. In a continuously violent situation, a sudden or sharp economic decline can be a threshold for generating a migration. In ongoing and harsh economic circumstances, sudden and persistent violence can signal the local population of its inability to continue to stay in that area. One theory that encompasses this idea is the Dread Threat Theory, which applies to populations that sense an ongoing and persistent dread or anticipate a future threat. Finally, given the need for these circumstances to persist, one must incorporate a lag in migration between the trigger event and actual movement.

Perception is key. How long will this threat last? Will it go away soon? Such perceptions inform where people go and when. They will stay close if they feel the threat will go away after a short time or they will choose to travel much farther when they believe the threat will continue for years to come, particularly if they have young children whose education and future will be negatively impacted by the emerging situation. The presence or absence of humanitarian actors and policies can also determine destinations. For example, Syrian refugees did not travel to Cyprus, which was closer, because Cyprus does not allow family reunification for refugees. Lately, Syrian men have returned to Syria because Germany refused to allow reunification with their wife or fiancé.

Migration will also not look the same in all countries. A dynamic, flexible general migration model can capture these variations with the help of subject matter experts (SME). For example, in Yemen, a country with both violence and ongoing poor economic conditions, hardly anyone has departed. Borders surrounding the country are generally closed and the immediate prospects in neighboring countries do not appear to be any better than their own. On the surface, the indication is that some populations should choose to flee, but this is not occurring, and this impression is further reinforced by refugee flows from East Africa moving into Yemen, despite the war. This indicates that SME input is needed to refine the migration expectations and tipping points in discrete ways to adjust the model to reflect actual circumstances.

In another example of how migration differs between countries can be found by comparing circumstances in Venezuela and Syria. A large part of Venezuela's population has already left, despite the fact that this situation is quite new (2019). By contrast, only a quarter of the Syrian population has migrated internationally after nine years of war. (This figure does not include the internally displaced persons. When those figures are included, the percent is closer to 66%).

A final example is Dera'a, the village where the Syrian uprising began. The community there is poor, leading many non-experts to predict that few would leave; however, a SME should actually be able to identify this as a potentially mobile population. The reason for this is that the population of Dera'a worked primarily with international networks, albeit often illegal, and after their predominant form of livelihood, agricultural work, declined over the preceding decade (due to regime policies of economic reform), they still had a series of established networks, international connections, and even marriages across national borders that provided them the potential routes out of danger. They also represent a tight-knit identity group due to their involvement in those illegal activities, which partly explains their activism in support of some members of the community at the start of the uprising.

With these insights and others from the data on migration, one can generate a predictive model whose outcome can then be input into a population migration model. Using subject matter experts, one can input thresholds that hold true for the local reality, include population characteristics, and provide newfound destinations for migrants. Access to information technology has allowed a wider breath of potential destinations as refugees share information and use mobile apps to allow them to move separately. Parameters can be set for individual cases, and one can determine the likely result given that set of variables for that country or region. Based on these factors, the NPS team modeled thresholds that would trigger population migration. These included:

- A civilian group's perceptions of quality of life and safety to determine **WHY** they would leave.
- A civilian group's affinity[4] with civilian population groups in feasibly reachable locations to determine **WHERE** they would go.
- A civilian group's perception of the magnitude of change over time in terms of quality of life and safety to determine **WHEN** they would leave.

POPULATION MIGRATION MODELING APPROACHES

Assessing Civilian Group Satisfaction and Affinities Using Deterministic Modeling Approach: Athena

After an extensive review of the extant PMESII/DIME models capable of representing the operational environment, both within DoD and the larger academic/commercial environment, NPS found the modeling framework provided by the Athena Simulation to be more pragmatically useful than any of the discoverable alternatives thus far.

Athena is a sociocultural modeling capability and decision support tool which supports staffs, commanders and/or other decision makers by providing both a framework to better understand complex PMESII-PT -based problems, and a simulation for computationally assessing the long-term consequences of employing various engagement options across the OE. Athena enables the analysis of second and third order effects upon noncombatant groups and their possible responses in order to discern potential outcomes from political, military, economic and social interventions. Athena allows leaders and analysts to understand the intended and unintended consequences of their proposed actions through a simulation process that incorporates social science 'universals' into course of action analysis and campaign planning. The Athena program was established by the US Army as an innovative approach to modeling the OE.

Leveraging an Agent-Based Model to Assess Why, Where and When People will leave: SoReM

SoReM is a prototyped next-generation model of the OE. SoReM is architecturally founded on the supposition that a social identity dynamics model must be at the core of any PMESII/DIME model which aspires to adequately understand, anticipate and/or influence non-trivial social behavior. A substantial part of this effort was dedicated towards attempting to frame the challenge of modeling social identity dynamics. According to NPS any model of the operational environment, which is not founded on a solid bedrock of social identity dynamics, will eventually be doomed to fail to deliver satisfactory results for all but the most trivial and semi-trivial classes of anticipatory social behavior challenges.

Social behavior is 'complex'. No truly useful model of social behavior will ever be derived from a simple cause-effect model. Unfortunately, humans, as cognitive beings, are unduly drawn to linear models and we are easily

[4] In Athena affinity has a specific meaning. This reflects a "birds of a feather" situation, thus "we are alike in terms of demographics and beliefs so if I go there I should be able to get along in peace".

confounded by even simple non-linear models. Nevertheless social behavior can only be reasonably modeled as a complex (feedback) system and one will simply have to be resigned to the fact that computational/generative models will spit out better predictions than human intuitions can grasp.

Key amongst the driving non-linearity of cognitive social systems is the constantly evolving structure and dynamics of the constituent identities at multiple levels. Who's playing the game isn't static … as much as some would love it to be. One needs to understand and explicitly model those identity dynamics and that requires at least an earnest shot at understanding the inherent and universal drives of any embodied cognitive agent.

Additionally, one must understand how these population drives and the sensed trajectories of their satisfaction state (e.g., safety and quality of life) impact both non-cognitive habitual responses as well as the cognitive responses. Finally, one must understand how emerging patterns of change in the environment trigger individual cognitive narratives, existing at various scales, differentially … and how those changes in the saliency of these identities are defined by those narratives.

Finally, there is the issue of what a SoReM and Athena federation looks like. Athena rightly should provide a 'service' to 'SoReM' in terms of noticeable changes in the environment, and thereby influence the dynamic evolution of SoReM's composite social identities. SoReM in turn should provide a 'service' to Athena in terms of changes in the nature and focus of collective high-level intentions operating in and guiding the pragmatic changes which are wrought upon the world by the various (changing) actors. See Figure 4.

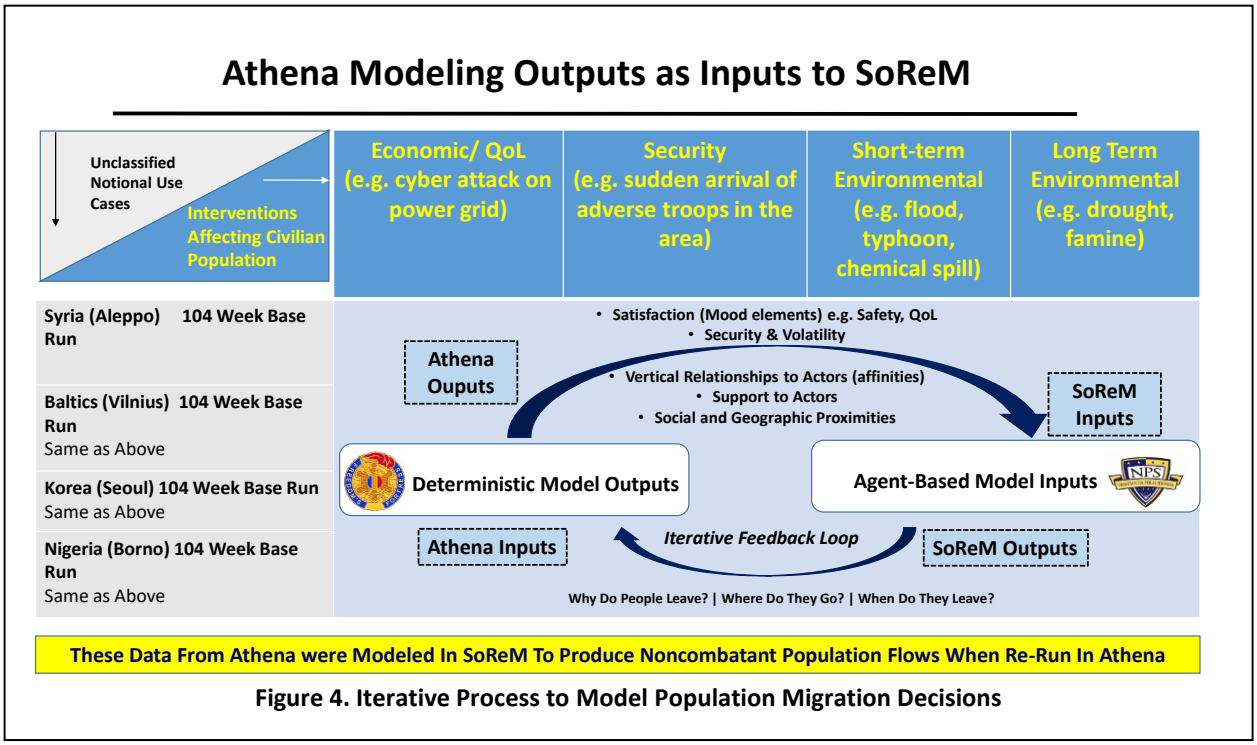

Figure 4. Iterative Process to Model Population Migration Decisions

OUTCOMES FROM THE STUDY

Deeper Knowledge and Understanding of Population Migration

This Army Studies Project provided a robust understanding and conceptual model for addressing the question of how, why and where human populations choose to migrate and has provided key factors for identifying the migratory tipping points for various people groups. One implication of this Study is that as future information operations and threatening physical events are initiated by adversaries in an area, this work completed by NPS will enable a better understanding of the second and third order effects of noncombatant population movements in the battlespace. Lessons

learned from this work will highlight how to better simulate and predict noncombatant movement and identify potential impacts in the OE using the methodologies developed in this important effort.

A General Model for Population Migration

NPS provided a General Model for Population Migration as shown in Figure 5. This model is generative, providing a good idea of numbers, pathways, and triggers. This concept model can be adapted by mathematicians and software engineers into an algorithmic methodology which can be incorporated into models and simulations for use by the Army, enabling a better understanding of the human stability dynamics affecting key regions. What would one include in this model? Many of the elements already discussed would be present, including networks, routes, baseline regional circumstances, potential triggers, and migration-specific demographic variables. A SME should be able to generate these parameters in a couple of days, and one can tap a wide array of such SMEs for whichever country happens to be the focus.

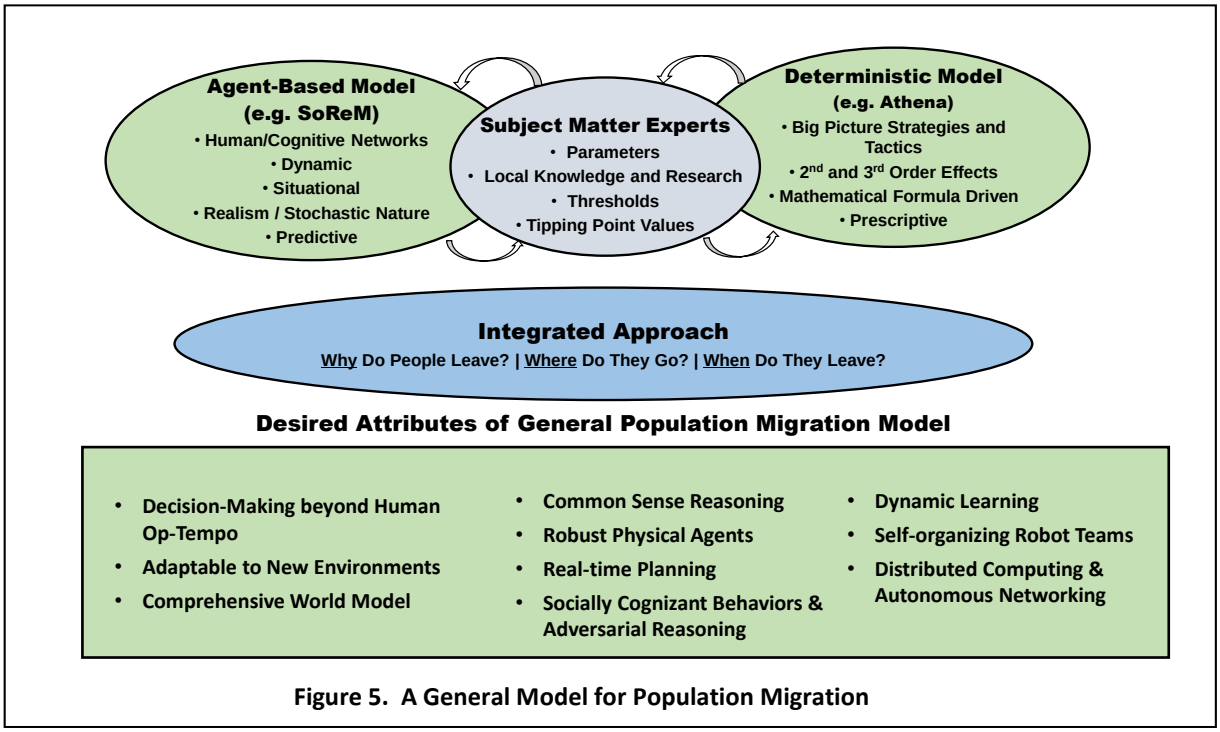

Figure 5. A General Model for Population Migration

A Near-Term Interim Path for Modeling Population Migration

The NPS Study team leveraged scenario information developed by the TRADOC G-2 MSO Athena team to demonstrate the results of employing the NPS social identity dynamics model, SoReM, to test its algorithm for anticipatory analytics to be used by Athena in order to assess noncombatant population migration in the battlespace. NPS' combination of SoReM and the Athena Simulation provided unique insights into OE characterization, risk assessment, synchronization, and course of action development. The lessons learned, drawn from the results of the Study, also highlight how using an agent-based model to provide anticipatory analytics for noncombatant population migration in the battlespace have enabled improved the Army's modeling of noncombatant population migrations and its understanding of migratory tipping points.

RECOMMENDATIONS

Study results included NPS developing a formal model of human migratory behavior and the development of a scripting methodology for integrating that model into Athena; which NPS assessed as a modeling framework that in NPS' judgment is the DoD's current premier PMESII/DIME modeling environment (see Figure 6.)

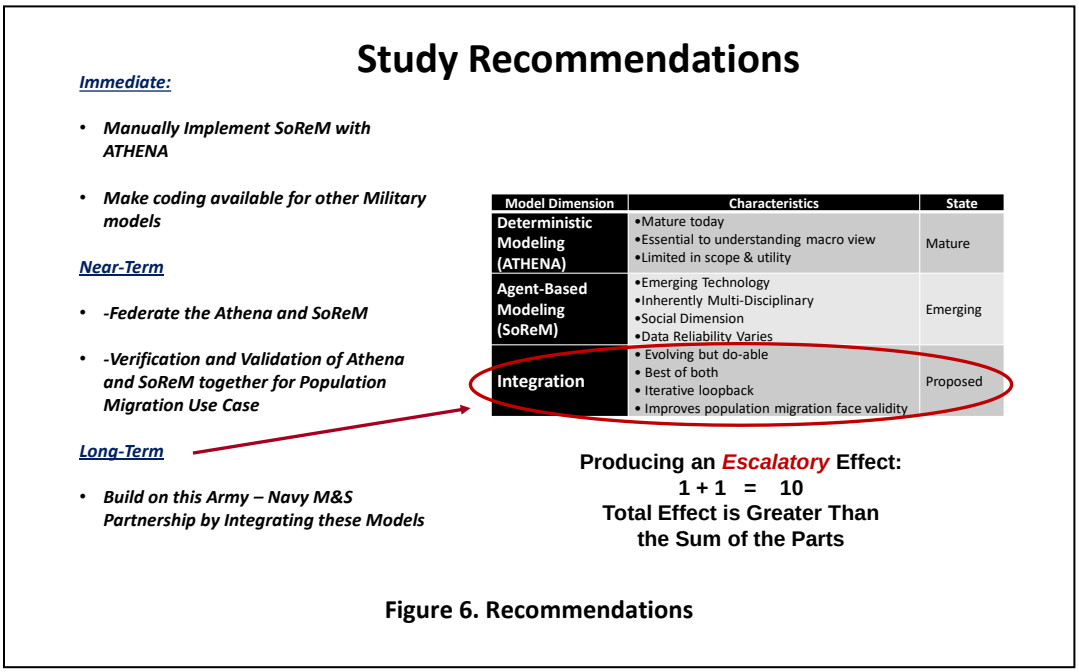

Figure 6. Recommendations

- **(Near-term) Make use of the NPS Script Coding for Conditional Movement (essentially, a Tipping Point Model)**
- **(Near-term) Make coding available for other models**
- **(Near-term) Verification and Validation of Athena and SoReM.** Continue efforts to provide a 'Face Validation' of the Athena Simulation and developing the concept for SME evaluations of Athena in accordance with DODI 5000.91. Test the accuracy of model by running historical migrations to gauge the accuracy of the assumptions programmed into both models.
- **(Mid-Term) Federate the Athena and SoReM Models** – Continue to develop the Cooperative Model Linkage Concept proposed separately by NPS. Delve further into whether and how SoReM might be federated with any PMESII-PT model such as Athena.
- **(Long-Term) Explore integration of Athena and SoReM -** Explore full integration as a proposed and prototyped next-generation model of the operational, using NPS methodology and model for population migration to simulate and predict noncombatant movement to improve our ability to understand, anticipate and/or influence non-trivial sociocultural behavior.

CONCLUSIONS

The NPS' combination of its agent-based model, SoReM, along with the Army's deterministic model, Athena, provided unique benefits to decision-making through improvements in OE characterization, risk assessment, synchronization, operational design and course of action development. The lessons learned from the results of using SoReM to provide anticipatory analytics for noncombatant population migration in the battle space has enabled an improved understanding of noncombatant population migrations and migratory tipping points. This means that as future information operations and physical events are initiated by adversaries in an area, this work completed by NPS will allow a better understanding of the first and second order impacts of noncombatant population movement in the battlespace. Lessons learned from this work will highlight how to better simulate and predict noncombatant movement and identify potential impacts in the OE using the methodologies developed by this important effort.

The NPS assisted the Army in the development of a concept model for the modeling of population migrations and tipping points, to include:

- A set of preliminary and detailed design documents that include the algorithmic underpinnings of the proposed migratory tipping point and movement models.
- Software that provides/structures the concept model and supporting algorithms in a code baseline.
- Documentation that describes the functioning of the software.
- A test plan for the emergent capability.
- An interface architecture that enables the Athena Simulation to provide sociocultural outputs to the NPS migration model that will enable a dynamic update to the status of the migratory population being calculated within the NPS model.

Using the deliverables developed by NPS, US Army commanders will have an increased understanding of the operational environment and may be able to mitigate an adversary's ability to degrade, disrupt, or otherwise manipulate a decision maker's understanding and decision cycle, or influence a population's will to remain in place or depart the area. Achieving cognitive windows of advantage requires careful consideration of how human factors influence the OE, the incorporation of human factors into campaign and operational planning, training, and exercises, and how operating with indigenous populations to shape the operational environment and conduct security activities can be achieved.

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