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Testing the peace support operations model with a scenario representing the instability in Sudan

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THESIS

TESTING THE PEACE SUPPORT OPERATIONS MODEL WITH A SCENARIO REPRESENTING THE INSTABILITY IN SUDAN

by

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March 2015

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13. ABSTRACT

Recent events in Sudan and South Sudan led to the creation of a peace support operations model (PSOM) simulation of the area for peacekeeping planning and analysis. This led to questions about how to best use the PSOM and how the PSOM reacts to certain inputs.

Major outputs of the PSOM are population consent for the rulers and the opposition. Designed experiments systematically explored the sensitivity of consent to initial values, showing that initial consent has a strong influence on ending consent, and initial consent values of zero do not allow consent to increase over time. Consent changes for a given course-of-action decrease over time, meaning that a course of action that leads to strong improvement initially will result in less improvement in later periods. The stochastic mode does not affect consent outcomes. An experiment varying courses of action for five factions in the contested Abyei region at the border of Sudan and South Sudan showed that rules of engagement have a significant effect on security and consent values but cluster around a few ending points. Consent values stabilize after about 30 model turns. These findings may be useful for military planners or for those developing training simulations for officers and leaders.

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TESTING THE PEACE SUPPORT OPERATIONS MODEL WITH A SCENARIO REPRESENTING THE INSTABILITY IN SUDAN

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Recent events in Sudan and South Sudan led to the creation of a peace support operations model (PSOM) simulation of the area for peacekeeping planning and analysis. This led to questions about how to best use the PSOM and how the PSOM reacts to certain inputs.

Major outputs of the PSOM are population consent for the rulers and the opposition. Designed experiments systematically explored the sensitivity of consent to initial values, showing that initial consent has a strong influence on ending consent, and initial consent values of zero do not allow consent to increase over time. Consent changes for a given course-of-action decrease over time, meaning that a course of action that leads to strong improvement initially will result in less improvement in later periods. The stochastic mode does not affect consent outcomes. An experiment varying courses of action for five factions in the contested Abyei region at the border of Sudan and South Sudan showed that rules of engagement have a significant effect on security and consent values but cluster around a few ending points. Consent values stabilize after about 30 model turns. These findings may be useful for military planners or for those developing training simulations for officers and leaders.

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LIST OF ACRONYMS AND ABBREVIATIONS

CECA	Critique, Explore, Compare, and Adapt model
COA	course of action
DSTL	Defence Science and Technology Laboratory
FP	force protection
ISAF	International Security Assistance Force
JEM	Justice and Equality Movement
MSER	Mean Squared Error Reduction
NATO	North Atlantic Treaty Organization
NOAB	nearly orthogonal and balanced
NOLH	nearly orthogonal Latin hypercube
NPS	Naval Postgraduate School
ORBAT	order of battle
PSO	peace support operations
PSOM	Peace Support Operations Model
ROE	rules of engagement
SEED	simulation experiments and efficient designs
SLA	Sudan Liberation Army
TRAC	TRADOC Analysis Center
TRADOC	U.S. Army Training and Doctrine Command
XML	Extensible Markup Language
U.N.	United Nations
U.S.	United States

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EXECUTIVE SUMMARY

The peace support operations model (PSOM) is a valuable platform for modeling insurgencies and non-traditional combats. While it has only primitive force-on-force modeling tools, it also models the consent of the populace toward governing and insurgent forces and how secure they feel during a conflict. Because the best way to end an insurgency is to make the population feel safe and happy with the government, this simulation is far better than a traditional wargame at modeling successful strategies for a peacekeeping or occupying force (such as in Iraq or Afghanistan).

This thesis examines a PSOM scenario intended to portray the potential difficulties of a mission to assist Sudan and/or South Sudan, both looking at the scenario itself and the PSOM model. The interaction of peacekeepers with seven active ethnic groups, each with an active faction, along with two governments is an opportunity to create both a rich and realistic training environment and to model an actual possible future conflict/peacekeeping area to help U.S./allied forces in such an endeavor.

Initial tests show that the stochastic mode in PSOM affects only the casualties of units, not the consent and security value changes in the population. This means that it can safely be ignored in simulations that are focused solely on those outputs. It is, however, possible that if there were more combat units in a smaller area, where extensive casualties could occur, that changes in unit strength could make the stochastic mode valuable for simulations not focused on casualties.

Another discovery is that setting initial consent or security values to zero can result in unexpected behavior. Although the values are displayed over a range from zero to ten, in the underlying calculations of the program they actually run from negative infinity to positive infinity, and an initial setting of zero means it is almost impossible to raise to the point where consent or security values influence population activity.

A small experiment explored how consent values change over time for two scenarios: the “protect” scenario, where all sides protected their own population, and the “withdraw” scenario, where all military forces withdrew from combat completely. The

results show that the changes are based on the initial input values. In other words, a given course of action does not cause consent to always drop by one point or to always move to a particular level given enough time. Instead, it would drop by an amount apparently related to how close the initial value was to six. Starting values close to six resulted in large changes to consent over time, starting values that were very high or very low resulted in much smaller changes to the consent values. This appears to be related to the nonlinear nature of the underlying calculations.

A larger experiment varied the force protection (FP) and rules of engagement (ROE) for each of five different factions, adding "combat," "rampage," "genocide," and "half genocide" to the "protect" and "withdraw" scenarios for a total of six courses of action. A nearly orthogonal and balanced design was augmented with the base case scenario to specify 513 different scenarios to simulate. From the results, it was determined that the rules of engagement have a significant effect on security and consent values. When one faction is engaged in genocide against another faction, the defending faction and the peacekeepers gain more consent with "loose" rules of engagement, perhaps because this allows more pro-active combat to protect civilians. Security was also increased with higher ROE values, probably for the same reason.

The genocide scenario also revealed an issue with the program. In some cases, the population of a region declined below zero, causing the program to halt. Perhaps this can be fixed in future versions of PSOM.

While it was expected that a wide variation in rules of engagement and stances would result in a wide variety of outcomes, a parallel plot of the results shows there are only a few different outcome values for each faction. There was still a wide variation between those few values, but with few exceptions, consent values did not "spread out" over a large number of values, but instead clustered on a few points. This may be because the metric measured was "change in consent" rather than consent, but it is more likely that there is some sort of "step" system in the program, or that the nonlinear nature of the internal numbers is only allowing changes if some key value is breached.

Finally, a simulation output analysis technique called MSER (mean squared error reduction) was used to determine that consent values became stable after about 30 turns with no changes in faction stances or activity. This could be useful for creating a baseline/starting consent for a new scenario. It could also be useful for comparing several possible reactions quickly. If the user programs a specific set of stances for a faction and runs the scenario to turn 30, they will have a good idea what it will look like at any turn after 30. As long as you are only looking at consent values, a single run will suffice because of the limited nature of the stochastic mode.

In summary, this thesis provides guidance to potential users of PSOM in several ways. It identifies considerations that a user should consider when setting up a scenario, such as the composition of map squares and the choice of initial values for consent and security. It gives guidance for running the model, such as when it may be valuable to run in stochastic mode instead of deterministic mode, and how many model turns are required to reach stable consent and security values for the many factions. It illustrates how a designed experiment can be used to gain insights about the scenario itself. All these may be useful for a military planner either evaluating a future area of operations or seeking to develop a training simulation for officers and leaders, with the ultimate goal of seeking to win the hearts and minds of the locals in an insurgency or ethnic conflict.

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I am also grateful to Mary McDonald and Steve Upton, who not only ran my scenarios on the SEED Center Computer Cluster but also helped me to understand what limitations they had to observe and to maximize the saliency of the work they did for me. Without their support and advice, my research would have been based on much smaller and less interesting data sets.

I would also like to thank my father for all of his support while I worked on this thesis. Finally, I would like to thank my kids for supporting me in this effort, Brenda, Celeste, Aaron Jr, and Daniel. This thesis is for their future, not mine.

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I. INTRODUCTION

A. BACKGROUND

In 2012, at the request of U.S. Navy Lt. Cmdr. Ryan Klaahsen of the U.S. Marine Corps' Combat Development Command, Dr. Jeffrey Appleget assigned his Wargaming class at the Naval Postgraduate School (NPS) the task of creating a wargame based on stopping a mass atrocity, instead of the normal wargames of force-on-force combat. The students decided to model the Abyei region on the border between Sudan and South Sudan, and the "peace gaming model" was so successful that it was presented at the International Association of Peace Training Centers Conference in Helsinki.[1]

There are many reasons why the states of Sudan and South Sudan, and the Abyei region claimed by these states, are important to the U.S. military, especially the U.S. Africa Command (AFRICOM). First is the public interest: the Darfur Genocide drew a lot of public attention and calls for the United States to intervene, and even a U.S. vice president called for intervention.[2] Second is the location of Sudan and South Sudan, bordering (among other nations) Egypt, Libya, Ethiopia, Eritrea, and the Democratic Republic of Congo. Third is the obvious assertion that instability in one nation can lead to instability in neighboring nations. This is backed up by accusations made by the government of Chad that Sudan was supplying arms to rebel groups in Chad.[3]

Also, the Sudan/South Sudan situation of multiple tribal groups, concern by tribal groups regarding favoritism by government groups and possible genocide, is similar to the concerns in other areas of interest to AFRICOM, and any lessons learned by studying a simulation of possible events in Sudan would be likely to also apply to other nations

[1] Kenneth Stewart, "Waging Peace, NPS Students Develop Peace Gaming Model," news release, Defense Video & Imagery Distribution System, last modified September 28, 2012, http://www.dvidshub.net/news/95488/waging-peace-nps-students-develop-peace-gaming-model#.UmF7hUDiXm4.

[2] Wasil Ali, "US Presidential Contender Calls for Military Intervention in Darfur," *Sudan Tribune*, May 21, 2007, http://www.sudantribune.com/spip.php?article21982.

[3] Lydia Polgreen, "Chad Says Sudan Is Arming Rebels," *New York Times*, October 25, 2006, http://www.nytimes.com/2006/10/26/world/africa/26chad.html?_r=0.

with similar situations. For example, Somalia was torn along ethnic lines, and involved accusations of at least passive genocide—in the form of intentional deprivation of food.[4]

Because of this success of the Abyei simulation, AFRICOM requested that TRADOC Analysis Center (TRAC) in Monterey (co-located with NPS) develop a simulation covering the greater Sudan area, including South Sudan. An area of 650 miles square was eventually selected for modeling purposes, encompassing Abyei, most of Darfur, the northern portion of South Sudan, South Kurdufan, and other portions of southern Sudan. This area contained portions of several possible hostile groups, while avoiding some of the more peaceful or distant areas that were unlikely to impact an Abyei flare up. While there are almost 600 ethnic groups[5] in the target area, the simulation modeling effort narrowed it down to the seven largest and most likely to participate in hostilities. This resulted in some odd combinations to account for the total population. For example, the Nubian tribe was considered to be "Arab," as it was located in Sudan and not generally rebelling against the Arab government, despite obvious differences in ethnicity and culture.

Events in the region argue for continued interest and work on simulation. In June 2012, Sudan invaded the Unity province of South Sudan.[6] A year earlier, South Sudan invaded Heglig in the province of South Kurdufan.[7] In addition to events near the Abyei region, in Darfur, the Messeria have clashed with the Rizeigat[8] and the Murle continue to battle the Nuer.[9]

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[4] Charles Kenny, "Foreign Policy: Murder by Starvation," National Public Radio, July 27, 2011, http://www.npr.org/2011/07/27/138738773/foreign-policy-murder-by-starvation.

[5] "Sudan: Society and Culture," Sudan.net, last modified October 16, 2013, http://www.sudan.net/society.php.

[6] "South Sudan Reports Troop Invasion from North," Voice of America, June 10, 2013, http://www.voanews.com/content/south-sudan-reports-troop-invasion-from-sudan/1678930.html.

[7] Lesley Anne Warner, "What Might South Sudan's Invasion of Heglig Indicate about its Negotiation Tactics?" *Lesley on Africa*, April 26, 2012, http://lesleyannewarner.wordpress.com/2012/04/26/what-might-south-sudans-invasion-of-heglig-indicate-about-its-negotiation-tactics/.

[8] Abdallah Abul Bashar, "Misseiriya and Rezaigatâ, Why Fighting Renewed?" *Sudan Vision*, July 23, 2012, http://news.sudanvisiondaily.com/details.html?rsnpid=212713.

[9] "UPDATED: Murle Revenge Attack on Luo-Nuer 'Kills 23' in Jonglei's Akobo County," *Sudan Tribune*, January 9, 2012, http://www.sudantribune.com/spip.php?article41226.

B. PSOM INTRODUCTION

The peace support operations model was designed by the Defence Science and Technology Laboratory (DSTL) in the United Kingdom to model insurgencies and counter-insurgencies in a totally new way. Instead of focusing on combat losses and casualties, it focuses on the outcomes for the population living in the simulated region. The primary output measure of PSOM is the "population security" metric, which measures the population's perception of safety from attack. Another main output is "population consent," which measures the willingness of any given ethnic group to be ruled by a given faction.

PSOM tracks unit casualties, unit readiness and training levels, the range at which units in different map squares can engage each other, intelligence-gathering efforts, and other combat parameters. Units are able to combat foes directly but are also able to provide security or conduct public works, which improve the lives of the population. Unsurprisingly, the latter activities sometimes are more effective at winning an insurgency than overt combat. Insurgent and local units are able to recruit additional members depending on the level of consent in the area.

Earlier work involving PSOM includes a thesis[10] that explores the utility of PSOM for training purposes, by assessing PSOM's sensitivity to a large number of model parameters. The findings reveal that the operational risks, rules of engagement, and risk tolerance are analogous to doctrine, and that the results are overly sensitive to only a handful of parameters. The *Journal of Defense Modeling and Simulation* had a special issue about PSOM in April 2011.[11] In this issue, they discuss how PSOM has a robust system for tracking logical changes in population attitudes toward factions based on how each faction provides for the needs of the population, including security as well as goods. However, humans are not logical, and so this set of articles also discusses a number of

[10] Benjamin J. Marlin, "Ascertaining Validity in the Abstract Realm of PMESII Simulation Models: An Analysis of the Peace Support Operations Model (PSOM)" (master's thesis, Naval Postgraduate School, 2009).

[11] Noel Wilde, "Special Issue: The Peace Support Operations Model: Stabilisation Strategy," *Journal of Defense Modeling and Simulation: Applications, Methodology, Technology* 8, no 2 (April 2011)

proposals to help PSOM better track real human responses, both using the Critique, Explore, Compare and Adapt model (CECA) and other methods such as new stances that units can use and using human in the loop analysis and manual changes to the base information.

C. PURPOSE

This thesis focuses on three areas of research concerning the internal workings of PSOM and how they affect both the designer of training simulations and the designer of simulations intended to model real-world locations.

Firstly, exactly how important is the "stochastic" part of the model? Is it worthwhile for a simulation to be run, say, 50 times in stochastic mode to check the validity of the first run, or are effects minor?

Secondly, how important are the initial values of inputs like "consent" and "security?" These are representations of attitudes of a broad population, which are often difficult to measure or survey. It is comparatively easy to count the number of troops and weapons different forces have available than to determine who has what support from the local population.

Thirdly, how do the effects of various setting change over time? Most existing analysis of PSOM has focused on the effects after a set number of turns. This analysis finds that a policy's effects decrease over time in PSOM.

In addition to these research questions, Appendix B contains the lessons learned and provides a short user's guide for new users of PSOM.

D. RESEARCH SCOPE

The research questions are addressed in the context of a single scenario. Even so, the biggest limitation on a research effort such as this is the sheer size of the experimental space. Even when restricting the study to a single PSOM scenario, there are nine factions, dozens of military or para-military units, and 144 grid locations each with at least one ethnic group represented as a "population agent." Each unit has potentially 59 actions they can take, and there are hundreds of "background settings" that can affect the results.

To simplify the experiment, the scenario is restricted to just six factions, one being the United States/United Nations troops (denoted by U.S./U.N.) and one being the Sudan government. The other four factions are paired into a simple two-sided war, with the U.S./U.N. acting as peacekeepers. Rather than model every action each military unit can take, all units are given a similar set of orders, such as defending themselves, attacking foes, or genocide; the U.S. is given roles consistent with peacekeeping in that situation. There are six order sets in all, ranging from all forces withdrawing and not engaging in combat, to one or both sides engaging in genocide.

Of the hundreds of background parameters that PSOM allows a scenario designer to change, only ten are varied in this experiment space. Previous studies had suggested that the rules of engagement (ROE) and force protection (FP) parameters were most important, so these parameters are varied for each of the five factions with military forces involved in the combat.

One of the main differences between this thesis and other research analyzing PSOM or other peace support simulations is a focus on changes over time. Marlin's thesis, for example, focuses on the results at static points in time, specifically at turn 12 or turn 24.[12] A reason this is important is that the curves that display changes in consent or security values over time frequently appear logarithmic. Most of the major change happens in the short run, and latter changes are much less noticeable.

E. THESIS ORGANIZATION

Chapter II of this thesis describes the environment that military peacekeeping planners currently face. First is a discussion of the need for peacekeeping training and planning, and the challenges compared to traditional war games. Following this are a more detailed discussion of what PSOM is, followed by information about how PSOM works. Chapter II concludes with a description of the development and design of the PSOM Sudan scenario.

[12] Marlin, "Ascertaining Validity in the Abstract Realm," 96.

Chapter III explains the techniques and methodology used to analyze the functioning of the Sudan scenario in PSOM, starting with a look at how logical the consent output is for determining the success of training or planning. The chapter also includes a discussion of the nearly orthogonal and balanced (NOAB) design used to analyze the interactions of ten variables across six scenarios using only 3,078 data runs instead of millions.

Chapter IV shows the data obtained from the computational experiments. First, it shows the results of a test of the effects of selecting the "stochastic mode" when running PSOM simulations. Then it displays the results of testing how the final consent values were related to the initial consent value inputs, intended to determine how important the accuracy of these inputs was to the proper running of the scenario. Finally, this section shows the results of the main scenario. It drills down into results for one tribe and attempts to determine the driving inputs for that tribe as an explanation of PSOM's internal workings. It also illustrates a simulation technique suitable for determining when time-dependent simulation outputs, such as consent values, reach stable values.

Chapter V summarizes the conclusions reached by this thesis and provides guidelines for further research. Appendix B contains some lessons learned for new users of PSOM, and provides a short user's guide.

II. BACKGROUND

A. WARGAMING VERSUS PEACEKEEPING

The United States has engaged in peacekeeping many times over our history. Major operations included Germany and Japan in World War II, Iraq, and arguably the local government support operations in Vietnam and Afghanistan. Absent the danger of commitment of Soviet troops in Korea or Vietnam, the last military conflict that presented actual danger to the United States was World War II.

The U.S. and allied military planning (wargaming) staffs in World War II were obviously successful (or this report would be in German). There was significant planning for the peace as well, a "large number of U.S. and allied military forces in West Germany and the establishment of a strong constabulary force preempted most resistance." Because of this, "no resistance of consequence emerged then or at any time thereafter,"[13] in Germany.

Similarly, Japan was relatively peaceful during its occupation. Initially, planners proposed using two full armies (the 6th and 8th) to either conquer Japan (operations Olympic and Coronet) or occupy it (operation Blacklist).[14] The idea that two full armies would be required even if Japan surrendered indicates how serious MacArthur was about the dangers of occupying a former foe.

However, by October 7, (WWII ended in Japan on September 2, 1945, with the signing of the surrender), the lack of resistance occasioned the transfer of the Marine Air Group stationed over Tokyo back to the Navy, and by October 15, the Air Group was

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[13] James Dobbins et al., *America's Role in Nation-building: From Germany to Iraq* (Santa Monica, CA: RAND, 2003), 21.

[14] General Staff of Douglas MacArthur, "Chapter I: Prelude to Occupation," in *MacArthur in Japan: The Occupation: Military Phase, Volume I Supplement*, ed. General Staff. (Washington, DC.: U.S. Army, Center of Military History, 1966). http://www.history.army.mil/books/wwii/MacArthur%20Reports/MacArthur%20V1%20Sup/ch1.htm.

primarily providing transportation (including mail and courier service) and doing training flights. Small wonder they were returned to the U.S. in June of 1946.[15]

There was evidence of resistance, but it was often brawls between U.S. service members and local men over romantic liaisons with local women, or local people throwing rocks at the U.S. forces. Rail line sabotage, gunfire directed at U.S. trains, and cutting of telephone wires was also reported.[16]

Vietnam was the first major "peacekeeping operation," where the U.S. arguably failed. Part of the problem was the local leader, who used extreme reprisals, leading to a "self-fulfilling prophecy, as the insurgency gained momentum, Diem would get more repressive, which would create more insurgents."[17] Another issue was the U.S. question of whether to fight the North Vietnamese conventional army, the Vietnamese insurgency, or both. In 1964, General William Westmoreland decided that "the North Vietnamese were more important because they were a larger threat at the present than the insurgents."[18] Of course, we all know the historical result of this. "Although when we left Vietnam in 1973 the North Vietnamese army had retreated to its borders and there was peace for three years, the United States counterinsurgency mission in Vietnam failed."[19] The insurgency won what the conventional forces could not.

Arguably, one of the most important lessons of Vietnam was that military force, and military victories, would not win a war where insurgency was an element. The United States won every major battle. Our troops beat back the Tet Offensive, and massacred the troops that attacked during that fight. We forced North Vietnam to the

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[15] Henry I. Shaw, Jr., *The United States Marines in the Occupation of Japan* (Washington, DC: Headquarters, U.S. Marine Corps, Historical Branch, G-3 Division, 1969).

[16] Bertrand M. Roehner, "Assaults and Sabotage against Allied Forces during the Occupation of Japan," University of Paris, June 17, 2007, http://www.lpthe.jussieu.fr/~roehner/ocj1.pdf.

[17] Christopher Millson, "Comparing Counterinsurgency Tactics in Iraq and Vietnam," *Student Pulse* 3, no. 5 (2011): 1, http://www.studentpulse.com/articles/531/comparing-counterinsurgency-tactics-in-iraq-and-vietnam.

[18] Ibid.

[19] Ibid.

negotiating table, and left as victors, only for the insurgency to return again, strong as ever, and take over Vietnam.

There is some question of whether it makes sense to include Somalia in the list of U.S. occupations. The exact dividing line between U.S. occupations, United Nations (U.N.) occupations, and U.S. assisted U.N. occupations is fuzzy at best. However, even tangential U.S. involvement can expose our soldiers or Marines to risk, as this occupation proved. In addition, we have a responsibility to learn from any occupation, even if they are not ours, in order to best prepare our troops for insurgencies. The U.N. mandate in Somalia shifted from a desire to provide food aid to starving civilians, to an attempt to protect that food aid (when some factions started using control of food for political or genocidal aims), to a final major U.S. operation to capture one of the warlords performing such actions. In the resulting battle, facing a population that was clearly not friendly, 18 U.S. soldiers were killed, and 84 were wounded, in an operation that inspired the movie "Black Hawk Down."[20]

U.S. operations in Afghanistan were not technically an occupation, but, like the operations in Vietnam, we provided trainers and troops to help a local government. With multiple factions (primarily government and U.S. versus the Taliban, Hekmatyar, and Haqqani extremist groups,[21] the latter all conveniently on the border with the lawless Pakistani tribal areas) and multiple ethnic groups (Pashtun, Baluch, Hazara, Aimaqs, Nuristanis, Kirghiz, Tajik, Turkmen, and Uzbeks),[22] Afghanistan seems to be exactly the sort of problem PSOM was developed to deal with. However, even after more than ten years of U.S. and North Atlantic Treaty Organization (NATO) ally support, Afghanistan was still unstable, and arguably worse than ever before.[23] Afghanistan remained a war

[20] "Ambush in Mogadishu Synopsis," *Frontline*, September 29, 1998, http://www.pbs.org/wgbh/pages/frontline/shows/ambush/etc/synopsis.html.

[21] Anthony H. Cordesman, Adam Mausner, and David Kasten, *Winning in Afghanistan: Creating Effective Afghan Security Forces* (Washington, DC: Center for Strategic and International Studies, 2009).

[22] "Afghanistan and the War on Terror," PBS News Hour, accessed October 14, 2013, http://www.pbs.org/newshour/indepth_coverage/asia/afghanistan/map_flash.html.

[23] "Bleak 2013 Humanitarian Outlook for Afghanistan," *Integrated Regional Information Networks*, January 2, 2013, http://www.irinnews.org/report/97162/bleak-2013-humanitarian-outlook-for-afghanistan.

zone, with U.S. forces facing multiple insurgent or locally dominant groups, but there were signs of hope.

In Iraq, we again defeated every foe that fought us, while slowly losing the hearts and minds of the locals. Then in 2006 or 2007, General David Petraeus led a movement of local protection. This "awakening" led to a 90% reduction in attacks in the formerly fractious Anbar Provence (though there were still problems).[24]

At this point, a wargame that only tracks military forces is great for winning a battle but not a war. The U.S. has not suffered anything as bad as Vietnam since, but in Iraq, we again saw the stark difference between winning battles and winning a nation. At the start of the Iraq war, we still had not developed models for the attitudes of the local population; nor did we have models for how our actions affected the local population, and their perception of our forces. We had no models to determine whether recruitment to terrorist or insurgency cells would replace losses to our attacks, or even surpass them. We had no models that could help us predict an awakening, much less encourage us to try to encourage one.

This is the job of PSOM.

B. PEACE SUPPORT OPERATIONS MODEL

> The Peace Support Operations Model, PSOM2, has been developed to represent the complete range of civilian and military activity in a Peace Support Operation.[25]

PSOM is a wargame designed for training military personnel in peacekeeping. It allows humans to control both the peacekeeping forces and the hostile forces, but also can support automated actions, primarily to test scenarios.

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[24] Alissa Rubin and Damien Cave, "In a Force for Iraqi Calm, Seeds of Conflict," *New York Times*, December 23, 2007, http://www.nytimes.com/2007/12/23/world/middleeast/23awakening.html?pagewanted=all&_r=0.

[25] Jon Parkman and Nathan Hanley. *Peace Support Operations Model Functional Specifications (PSOM-FS)* (UK: Ministry of Defence, Defence Science and Technology Laboratory/TR28869/1.0a, 2008), 6.

A major difference between PSOM and other wargames is the inclusion of a population element. While PSOM will track military capabilities and casualties, it can also track the local economy, population movement (including optional migration), and how the local population feels about their leadership and security. This presents a unique and powerful opportunity to look at a scenario not from the military dominance viewpoint, but from the viewpoint of winning hearts and minds. Given recent experiences in Iraq among other locations, this is an important viewpoint to develop in our officers.

PSOM has been used to train military officers from multiple nations in Monterey, CA. A group of officers from a single nation's military work together to plan responses in a fictional scenario, trying to help bring stability to the imaginary nation, rather than just trying to defeat or destroy the hostile forces. In the words of the program, this exercise is intended to "prepare a Partner to support and contribute to multinational peacekeeping and peace support operations, which reduces the requirements and burden on the U.S."[26]

Three of the four courses offered by NPS in Peace Support Operations (PSO) are based around PSOM. The first two are an initial five-day training in PSO for an O-3 to O-6 officer team sent by the hosted nation, and a follow-on five-day course. Both courses use PSOM to give realistic feedback for the actual courses of action chosen by those officers, acting as a team, controlling units, and coordinating their efforts. In order for these sessions to work currently, a "red team" has to choose reactions of the hostile and other local active players. This is currently a shortcoming of the program, as it is labor intensive. The hope is to eventually develop some form of reactive algorithm that would allow the program to be run much more quickly and give the officer team being trained the ability to run the simulation again, choosing a different overall strategy. Ideally, since PSOM saves each turn of the simulation, the officer could go back to a mistake and re-run the simulation from that point, starting with a different key choice. Such a capability would also allow the trainers to run the simulation a second time with different rules of

[26] Naval Postgraduate School, "Peace Operations," August 2012, 7, http://www.nps.edu/About/USPTC/Programs/Peace-Operations.html.

engagement (ROEs), firepower ratings, or initial consent values, giving the officer team being trained a feel for how such changes would affect a real-world situation.

Currently, PSOM training by NPS uses a simulation based on the fictional island nation called Yellowstone. The intent of using a fictional nation is to avoid offending anyone or having any questions about the reality of the simulation. Yellowstone has two islands, with five ethnic groups and a deteriorating government. Three U.N. brigades are sent in with the mandate to:

- Support a secure and stable environment,
- Support the constitutional and political process, and
- Promote and protect human rights.[27]

These objectives are similar to what would be expected for any peacekeeping mission. Similarly, the multiple ethnic groups and tension between ethnic groups are what would be expected in almost any U.N. peacekeeping mission, or indeed any stabilization mission for any governmental body (e.g., U.S. and coalition actions in Iraq).

On the first day, the students develop a course of action (COA) and observe the training team entering the first day's orders, asking questions as needed to understand the process. On the second day, the students are able to enter their own orders, though currently they provide verbal orders and the training team enters that as data into PSOM. The third day is the first day that the "red team" responds to the students' entries, and day four is a turn where both teams are fully engaged. Finally, the fifth day is a day of analysis of lessons learned, an opportunity to teach based on the strengths and weaknesses observed during the session.[28]

The question is this: Is PSOM just for peacekeeping training, or can it be used to consider real-world scenarios? If the latter, can it be used to examine different options in

[27] Jeffrey A. Appleget, "Using the Peace Support Operations Model (PSOM) for UN Peacekeeping Operations Training and Education," PowerPoint presentation, U.S. Partnership for Peace Training and Education Center, Naval Postgraduate School, August 2012, 7, http://www.ismor.com/29ismor_papers/29ismor_appleget.pdf.

[28] Ibid., 9.

those scenarios? PSOM has been used to model both Iraq and Afghanistan, and has also assisted ISAF (NATO) planning in Afghanistan.[29] "The PSOM's game system is generally consistent with emerging U.S. and UK Concepts and Doctrine (for example, U.S. FM 3–24 (Counterinsurgency) and FM 3–07 (Stability Operations) and their approximate parallels JDP 3–40 and AFM COIN)."[30]

It is also being used by Canada, Japan, Germany, Sweden, the Netherlands, and Australia,[31] in addition to nations that send officer teams to U.S. training utilizing PSOM at NPS.[32]

To determine how effective PSOM is for real-world simulations (as opposed to training), we need to understand the program. Two top-notch sources for this were the PSOM Functional Specification, which was understandably helpful as it described what the program was intended to do, and how it was intended to do it, as well as a master's thesis written by Major Benjamin Marlin in 2009.[33] Marlin did a thorough job of analyzing the experiment space, showing how changing different inputs affected the outputs. However, in a computer simulation there are often situations with outcomes that are not self-evident. Both my work and that of Marlin, therefore, perform experiments and analysis to determine how the results of PSOM relate to the inputs.

One of the goals of this thesis is to seek out and document such unexpected results so that future users of PSOM can anticipate these results, and either avoid them or take advantage of them.

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[29] Jeffrey A. Appleget, "PSOM Overview and Peacekeeping Operations Assessment Using PSOM," PowerPoint presentation, U.S. Partnership for Peace Training and Education Center, Naval Postgraduate School, October 2011, 3.

[30] Appleget, "PSOM Overview and Peacekeeping Operations," 5.

[31] Ibid., 8.

[32] Christopher J Nannini, Jeffrey A Appleget and Alejandro S Hernandez, "Game for Peace: progressive education in peace operations," *Journal of Defense Modeling and Simulation: Applications, Methodology, Technology* 10, no 3 (2013): 283–296

[33] Marlin, "Ascertaining Validity in the Abstract Realm."

C. HOW DOES PSOM WORK?

In order to understand the experiment space, a brief explanation of the program's inputs and operation are required.

There are two main files in a PSOM scenario, a settings file and a scenario file. In addition, the user should supply a map, which can be given further attributes in the scenario file.

The settings file determines global inputs like the size of map squares, the number of civilians represented by each "population agent," and the "memory coefficient" value for the simulation. These give the program a great deal of flexibility. It can model a small area, with 5 KM squares and population groups of 100 or 1000—or it can model a nation, with 50 or 100 KM squares, and population groups of 10000. These values are stored as numeric values, so any reasonable value can be chosen. (There are some restrictions. For example, population groups should be integers.)

While there are a large number of settings that can influence the scenario, the "memory coefficient" is a particularly interesting one for consent and security values. It determines how long a population agent "remembers" a positive or negative event. A low value of this setting results in quick changes to outputs as you change actions, while a high value leads to "stubborn" population agents who remember past wrongs for quite a while.

The scenario file gives the actual information about the nation involved, including the ethnic groups, the population sizes and locations on the map, and the resources produced by labor. Other information includes governments, rebel/militia groups, what military and humanitarian units they have to promote their causes, where on the map those groups are located, how many map squares they can affect in terms of engaging foes, and (once determined) what mission they have.

The scenario file is emblematic of the "two layer" philosophy of PSOM. An ethnic group might have its own leaders and militia, but the ethnic group population is part of the passive, civilian layer, while the militia is part of the active, military layer. When using PSOM for training, each faction is assigned to a single player, but the player

only controls the military units and humanitarian group units. The population groups react to conflicts using internal algorithms, so a population cannot be moved, used for a purpose, etc. Units are allowed to recruit locals to replenish combat damage however.

The population provides outputs that are generally the victory conditions of a scenario. The two most commonly used are "consent," which measures how willing an ethnic group is to be ruled by a given faction, and "security," which indicates how safe a group feels. In addition, outputs representing humanitarian considerations, such as crime level or infrastructure, can be easily viewed and used as victory considerations.

Inputs are many and varied. The security and consent values have to be given starting values, though in the absence of an inputted value for security it will be set to 10 (meaning the population perceives no danger). Clearly, setting these numbers high will lead to a drop off in the early turns of a simulation regardless of the actions of the users. While each population agent has only one security number, there is one consent value for each population agent toward **every** faction. In other words, a given group of people will have an opinion about every possible group that seeks to control the nation or area. This makes sense, as any faction that might gain control will be of interest or concern to the population. Also, this helps determine possible recruitment by a faction's military or infrastructure support units, because an unpopular faction will have difficulty replacing casualties or increasing unit size.

Also, each map region has a production value associated with each owning faction. An owning faction produces, in each map square, the items in Table 1.

Table 1. Production factors in each map square

Income	Power	Sanitation
Potable Water	Education	Healthcare
Shelter	Information	Internal Order
Administration	Food	Transport
Military	Politics	Gold

Each faction has a production value for each of these 15 items in each map square. However, many of these values are going to be zero; a faction with no presence in a region will have a zero production, and foreign (e.g., U.S. or U.N.) factions will have zero production with occasional exceptions. In addition, there is a current infrastructure value and a human capital value for each of the 15 production factors for each faction. If you have only five factions, you have to input 15*5*3=225 numbers per map square. This is a daunting task, but the numbers can be accessed in the Extensible Markup Language (XML) layer and altered *en masse*, either ported from a spreadsheet or set to a default value.

These production values are part of the passive layer of PSOM, which means this production occurs regardless of the orders of the faction controllers. Note that foreign forces or agencies should have a zero production and current infrastructure, with rare exceptions, because those factions do not have local population/infrastructure/capital investments. However, the U.S./U.N. faction can produce these goods by having a unit engage in an action such as "Build/Humanitarian Aid > Build Infrastructure."

The ethnic groups themselves, in addition to the initial consent values, have an "ideology" setting which relates how groups feel politically. It uses a two-dimensional scale of personal and economic freedom, with authoritarian, libertarian, liberal, conservative, and centrist positions. Both dimensions are on a 100-point scale, allowing for differences between similar groups. Factions also have a setting using the same scale. Differences between a faction's ideology and the ethnic group ideology have an effect on consent.

The "Ethnic Groups" scenario entry also has demographics data (working age and school age percentage of population) and marginal gain coefficients for the fifteen production items (which determine the relative value to the faction of production or destruction of each of these goods).

Another major portion of the settings file contains the "Relationships" that set the way that factions interact with each other. Note that this does not affect the way factions interact with the local populations, only their interactions with each other. Faction

relationships with local populations are determined by actions, either producing or destroying infrastructure, attacking the local population, or engaging in combat near the population, thus causing collateral damage to local people or property.

Each faction has a relationship with each other faction, which can be "Attack," "Cease Fire," or "Protect." The attack action in theory allows a faction leader to direct their forces to attack another faction. In practice, you can order a military unit to attack even friendly military units. The cease-fire action means you will not attack, and the protect action directs your troops to join the selected faction's units in combat if they are attacked.

Another portion of the faction relationships includes two options. One is to "Share Intel," which allows a faction to see units on the map that the sharing faction has seen. The other is rather important but often overlooked. "Share Consent" means that actions one faction takes that affect consent will also affect the consent toward the other faction. This is useful if a quasi-military group is supporting the government but is a separate faction; its units are not part of the government faction. This can also be useful for modeling a U.S. force that is widely held by the local population to be supporting and allied to a local government.

Finally, each faction has "ORBATS," which is a term used for the military or humanitarian aid groups it controls. While the name is derived from "Order of battle," it also includes a two-part order system to tell the units what to do each turn (these orders can be altered every turn if desired).

Every unit has a "Faction," "Leadership value," "Reputation," "Experience Value," and "Casualty Tolerance." These determine how effective a unit is and how it reacts to combat. Each unit also has a given "ROE," "Force Protection" level, and a "Footprint" that determines how far away it can strike. The footprint value should be a multiple of the map square size, and most unit footprints are one map square. The unit's location is also entered, and again can be changed each turn.

The same page allows units to be given orders, in the form of a "Main Stance" and "Sub Stance." The main stance is a group of actions of a common vein, designed to

keep the large number of orders available from overwhelming a user. For example, the "Build/Humanitarian Aid" main stance contains the "Build Infrastructure," "Train Human Capital," and "Provide Aid" options, which are all related, and different from the sub-stances available in the "Attack/Enforce" main stance. After inputting the stance, a commander also has to provide targets. Options are available to identify "Faction Targets" (which other faction you wish to aid or harm), "Sector Targets" (the 15 production items), and "Population Targets" corresponding to the ethnic groups. Note that target is not always a hostile designation—the target of a "Protect" action will be defended from hostile actions, and the target of a "Build Infrastructure" will be the type of infrastructure improved.

D. EXAMPLE OF SCENARIO BUILDING (SUDAN)

The first step was to create a settings file; in this case, the team re-used the settings file from the Yellowstone scenario. The second step was to break the team up to work on the various inputs to the model. The major inputs were the military units for all sides, the ethnic group populations and locations, and the economic development factors. Of the three, I was assigned the work on the ethnic groups.

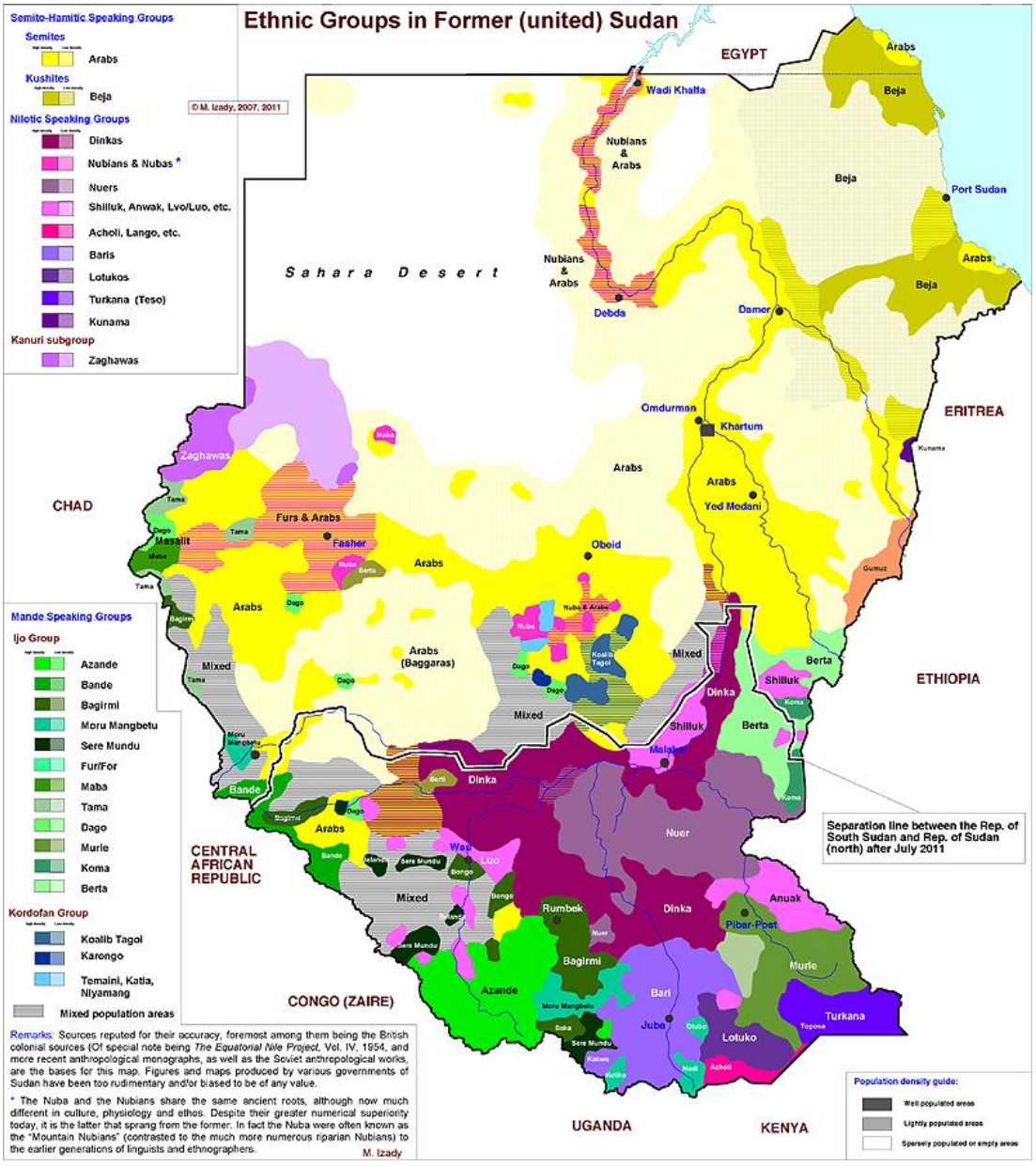
In the Abyei region, the primary protagonists are the Messiria and the Dinka (Jieng). In Darfur, there are Fur, Messiria, and Rizeigat, with some Arab presence. North and east of Abyei is home to mostly Arab groups, and South Sudan is primarily Dinka, Nuer (Naath), and Murle. This is obviously an oversimplification of the 600 ethnic groups,[34] but suffices to model major conflicts, even as it ignores situations like the Darfur violence between the Fur, Zaghawa, and Masalit, who all were nominally allies against the Janjaweed and Sudan government forces. In any case, the Zaghawa and Masalit territories are in west Darfur outside the area of the simulation.

Many of the ethnic groups are minor groups that are affiliated with a larger tribe or faction (similar to how the thousands of Iraqi tribes are all part of a few tribal groups, some of which cross religious or ethnic lines). Sorting out which ones were important to

[34] Sudan.net, "Sudan: Society and Culture."

potential conflicts and, for that matter, were within the area being considered, was a challenge. A map of the many ethnic groups in Sudan appears in Figure 1.

Figure 1. Map of ethnic groups in Sudan[35]



[35] Source: Michael Izady, "Ethnic Groups in the Formerly United Sudan," map, Gulf/2000 Project, accessed December 28, 2013, http://gulf2000.columbia.edu/images/maps/Sudan_Ethnic_Linguistic_sm.png.

A misunderstood element of the various conflicts is herd animals. In addition to arguments over grazing and watering rights, there is a lot of conflict over ownership of these animals for a more immediate reason. In many parts of Sudan/South Sudan, a man cannot get married until he has five cows or equivalent wealth. When a herder allows his animals to graze or take water from an area claimed by another faction, the other faction may claim part (or even all) of the herd because the cattle or camels contain the grain or water of the claiming faction. In addition, a quick (and accepted) way for a male to gain five cattle is to steal them from another tribe. Sometimes these raids involve fighting or even deaths, and even if the raid is bloodless, conflicts can arise afterwards.

1. Darfur Region

In the Darfur region, the major ethnic groups are Fur, Messeria, Rizeigat, Zaghawa, and Masalit.[36] When the original fighting in Darfur started, the Fur, Zaghawa, and Masalit were being pressured by the Arabs (Messeria and Rizeigat) over grazing and water rights. The pro-Arab government supported the latter administratively. Eventually, the non-Arabs joined the Sudan Liberation Army (SLA) and the Justice and Equality Movement (JEM) and other groups rebelling against the Sudan Government in protest. However, as land pressure pushed the three non-Arab groups from their original farms, they began to fight amongst themselves. JEM was mostly representative of the Zaghawa, and the SLA took many fighters in the region from the Fur,[37] meanwhile the Masalit, a smaller tribe besieged on all sides, created its own minor group.[38] The borders of the simulation did not include the areas where most of the Masalit and Zaghawa live, so the simulation only had to include the Fur, Messeria, and Rizeigat.

The original intent of the ethnic group compiler was to use only Janjaweed instead of splitting the Messeria and Rizeigat; however, they do represent different

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[36] "The Peoples of Darfur," Cultural Survival, accessed October 16, 2013, http://www.culturalsurvival.org/publications/voices/32/peoples-darfur.

[37] Omer Ismail and Maggie Fick, "Darfur Rebels 101," Enough Project, January 29, 2009, http://www.enoughproject.org/publications/darfur-rebels-101.

[38] "Cablegate: Chad/Sudan: Masalit Restiveness," *Scoop Independent News*, June 7, 2007, http://www.scoop.co.nz/stories/WL0706/S01015.htm.

groups, even herding cattle versus camels. In addition, in 2008 the two groups began to fight over water;[39] however, the groups have also fought because of differences in state support (the Rizeigat militia were generally placed in the Sudan Army, while the Messeria were mostly given policing jobs, which meant less weapons and equipment). Therefore, it made sense to make two different tribes. Also, the Messeria are engaged with the Dinka in Abyei (see the next section), but the Rizeigat are not in that area.

2. Abyei Region

The original area used in the game for peace, the Abyei region, only has two tribes claiming ownership, the Dinka and the Messeria. The Messeria had moved in and pushed a large number of Dinka out, and the region is now being disputed between Sudan and breakaway South Sudan. The region held a vote on whether to remain in Sudan or join South Sudan in October 2013.[40] Unfortunately, the Messeria boycotted the vote.[41]

The borders of the disputed region were re-drawn to make it smaller, which will reduce the number of (Pro-Sudan) Messeria. While this makes it more likely that the remaining region will decide to become part of South Sudan, the smaller area means that less of the oil-rich state would leave the economic control of Sudan. One important part of the referendum is that while only Messeria physically resident in the revised borders will be allowed to vote, all Dinka from the area will be allowed to vote. This is in response to allegations that many Dinka were forced from their homes in the region.[42]

The region is not only oil rich, but also is home to a lot of the oil refining and piping infrastructure, which explains its importance and why the government helped the Messeria drive Dinka from the area before the Sudan/South Sudan split.

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[39] "Efforts Underway to Reconcile Two Darfur Tribes after Bloody Clashes," *Sudan Tribune,* August 22, 2008, http://sudantribune.com/spip.php?article28373.

[40] "Ngok Dinka to Hold Abyei Referendum This Month," *Sudan Tribune*, October 19, 2013, http://www.sudantribune.com/spip.php?article48505.

[41] "Abyei's Dinka vote to join South Sudan," *Al Jazeera*, October 31, 2013, http://www.aljazeera.com/news/africa/2013/10/abyei-dinka-vote-join-south-sudan-2013103193942652913.html.

[42] Sharon Otterman, "Court Redraws Disputed Area in Sudan," *New York Times*, July 22, 2009, http://www.nytimes.com/2009/07/23/world/africa/23sudan.html?_r=0.

3. South Sudan

South Sudan was the first part of Sudan to rebel against the central government. While the conflict in Darfur was mostly along racial/ethnic lines (between government supported Arabs and rebelling ethnic Africans), the people in South Sudan were mostly Christian and/or Animist. This lent an air of religious conflict to the part of the succession war between the Christian South and the Islamic north.

Other than the dispute in Abyei, the Dinka, Nuer, Murle, etc., are mostly at peace with Sudan. They formed a new nation peacefully after the referendum. There have been border skirmishes in both directions, however.

Internally, there are still conflicts. The Nuer worry that the Dinka, as the largest tribe, will try to dominate the nation, and vigorously strive for representation and power in the government. Another complication is that the tribes were given land grants for grazing and farming by the British, and while the Dinka and Nuer were given large land grants, the Murle were not. This has led to competition and conflict between the Nuer and the Murle over grazing rights.

4. Eastern Sudan

The remainder of Sudan is mostly loyal to the Sudan government. Although the population is composed of many ethnic groups, including a large number of Nubians, I labeled all of them "Arab," for purposes of the simulation. The Nubians, Koalib, etc., may not be ethnically Arab, but as they follow the main government, they act as though they are part of the "loyal population."

5. Process Notes

Having determined the tribal groups, it remained to determine the actual populations and military units. While an attempt was made to make population units match the maps (see Figure 1 for an example), in reality the populations were mixed in almost all areas. In addition, having two or more ethnic group population agents in a grid square makes the PSOM simulation more active and therefore useful. If all grid squares

only had one ethnic group, then a conventional military simulation with military units guarding population agents would protect all population groups.

Most of the military units were tribal groups or militia. The mounted Janjaweed were made more mobile, and only given to the Rizeigat and Messeria. One problem noted with the early versions of the scenario was that there was minimal actual conflict. The military units started in separate grid squares and did not come close enough to fight. This was solved in later iterations of the scenario by better initial placement of units and placing additional units for each faction.

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III. METHODOLOGY

A. OUTPUT VERIFICATION

It does not matter how many Viet Cong fighters American soldiers kill if the group just recruits more. While standard military simulations output casualties or damage to units and weapons platforms, PSOM provides additional outputs based on the perceptions of the local population. Because a peacekeeping or counter-insurgent mission is based as much or more on the outcome for the local population than on the number of hostile fighters killed or captured, such outputs are the real measure of effectiveness for such missions.

The two primary "perception" outputs of the PSOM model are consent and security. Consent measures how willing the population of a given tribe or group ("Ethnic Group") are to be ruled by a particular faction. Security measures how safe and secure each ethnic group feels from violence or lawlessness. Because we want the fighting to stop, the consent value (the willingness of an ethnic group to fight rule by a given faction) is used. This is despite the fact that security is defined as the key measure of effectiveness (MOE) in PSOM.[43]

But how can we be sure that the consent output of the model represents what the population would actually tell us? At a gross level, we can run simulations of several inputs, and look at whether the outputs make sense. This is called Face Validation in the verification, validation, and accreditation (VVA) process, making sure the model is a representation of reality.

The consent values change each turn of the simulation, but someone has to put in starting numbers. But how do they know if those numbers are right? How do they interpret results if the initial inputs are wrong?

[43] Marlin, "Ascertaining Validity in the Abstract Realm," 23.

B. DESIGN INTRODUCTION

Modern simulation models can have very high processing requirements.[44] The author recently created a Lancaster simulation in Microsoft Excel where each soldier was identical. This took mere seconds to re-run when data points were changed, despite the inclusion of friendly fire, air support, different types of troops, and a defender's advantage. However, a simulation that tracks all soldiers in a conflict, lines of sight, weather, and logistics, or one that attempts to track the opinions of thousands of people from nine major tribal groups over 100 regions, has a much higher computer processing cost. Because of this, finding a "model of the model" or "metamodel"—a simpler mathematical formula that can predict the results of a simulation—can result in a huge savings in time and cost. In addition, if the timeliness of response is critical, it can save lives. Alternatively, such a design can allow analysts to pull many examples of different possible inputs, and analyze the outputs for trends. Because real life is complex, we may not know all of the inputs, or may have to rely on rough estimates. A robust model, based on an intelligent design, can allow you to see how resistant the conclusions are to minor inaccuracies in the inputs.

There are a few designs a simulation expert can use to make a model of the model. One of the first types developed (called a full factorial design) uses all combinations of the high and low levels of each input. The problem with this is that if you have only 100 inputs, you need to run 2^100 simulations to develop your model, which takes about 1,000,000,000,000,000,000,000,000,000,000 times as long as a single run (to put this in perspective, if one run takes one second, 2^100 runs will take about 40 billion trillion years). Another difficulty with this design is that by only looking at the high and low inputs, you will get very inaccurate estimates if the inputs effects are nonlinear. One soldier sent into battle will probably be killed, a million will have huge costs; a thousand might be just right, but if you only look at a single soldier and a million you will not see that.

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[44] "Developing Stressor Scenarios for Peace Operations through Experimentation," news release, Naval Postgraduate School, November 26, 2012, http://www.nps.edu/About/USPTC/NewsEvents/NewsArticles/2012/Developing-Stressor-Scenarios-for-Peace-Operations-through-Experimentation.html.

Newer methods that are much more efficient include the Nearly Orthogonal Latin Hypercube (NOLH) designs,[45] and the Nearly Orthogonal and Balanced (NOAB) designs,[46] which use larger numbers of variable input settings, and (by making sure that setting combinations are scattered in the high-dimensional space of interest), allows a similar level of analysis with far fewer runs.

Using a PSOM model of the tribes and forces involved in the region of Sudan developed by the simulation experiments and efficient designs (SEED) Center at NPS, a set of hostile actions was developed, and then a set of U.S. responses was created. The hope is that this will allow the future creation of models to predict which U.S. responses will be most effective without running the full simulation for each combination of actions and responses.

C. EXPERIMENT SETUP

We examine two primary research questions. The first involves the initial transient effects of population dynamics for the PSOM Sudan scenario. Key measures of effectiveness for PSOM scenarios include the aggregate measures of various demographic groups, such as the aggregate level of favorability a particular tribe has for the U.S. forces. Previous studies involving PSOM have focused either on the levels or on the changes in levels from the initial values, after a small number of turns. Depending on the scenario, a turn can represent a day, a week, or even a month; each turn represents one month in the Sudan scenario. They have used efficient experimental designs to vary large numbers of inputs, and identify key drivers of the behavior of these MOEs at a particular snapshot in time. We augment past studies by conducting a detailed investigation of the transient behavior of the MOEs across a large number of turns. These results may improve our understanding of the PSOM model behavior in general, as well

[45] Thomas M. Cioppa and Thomas W. Lucas, 2007, "Efficient Nearly Orthogonal and Space-Filling Latin Hypercubes." *Technometrics* 49, no 1: 45–55

[46] Helcio Vieira Jr, Susan M. Sanchez, Karl H. Kienitz, and Mischel C. M. Belderrain, "Efficient, Nearly Orthogonal-and-Balanced, Mixed Designs: An Effective Way to Conduct Trade-Off analyses via Simulation," *Journal of Simulation* 7(2013): 264–275

as specific behaviors for the Sudan scenario, by revealing how many turns are required for MOEs to stabilize, as well as the long-run values of these MOEs.

In addition to the transient behavior analysis, we examine the sensitivity of the MOE transient patterns to the initial conditions, troop actions, and troop capabilities. For example, increasing a starting sentiment for a particular tribe might result in a variety of behaviors. It could move the MOE curve up by a fixed amount. The MOE could take a slightly different trajectory but converge to the same value. The MOE could take a radically different trajectory and converge to a very different end state. Because the transient analysis involves looking in detail at time-varying MOEs, we use an efficient experimental design to specify a relatively small, but carefully chosen, set of model variants.

Rather than have units following some random or varied set of orders, courses of action for each side were designed to show a wide variety of actions, with most units doing the same (or similar) tasks. These designed scenarios give a broader range of alternatives, and will hopefully make the differences more noticeable, and capture any significant changes regardless of type of interaction.

1. Measures of Effectiveness

The primary measure of effectiveness we will be looking at is the "population consent" value of each population unit toward each faction. Population consent in PSOM is a number between zero and ten that represents how willing the population is for a given faction to be in control or in charge of the area the population lives in. Note that PSOM allows (in the faction settings) the person running the scenario to have population agents attribute the actions of one faction to an allied faction. For instance, in the Sudan example, the actions of the U.S./U.N. peacekeepers also could be regarded as representing the Sudan government, or the actions of the Arab faction could do so, since the Sudan government is dominated by Arabs.

While the population consent runs from zero to ten in output, PSOM itself uses a number between negative infinity (output as zero) to infinity (output as ten). This helps to explain some of the ways that PSOM outputs behave.

A successful set of policies and actions by the U.S./U.N. peacekeeping force would raise the population consent towards the U.S. One of the thorny issues of a situation like this is that while you would expect that a decrease in population consent toward the warring factions would be positive for the U.S., in practice this could represent further exacerbation of ethnic tensions, which could lead to hostilities sparking up again once the peacekeepers depart. Consent toward the ruling government is another goal of the peacekeeping force, as perceived legitimacy of government will help get the population to turn to the government, instead of conflict, to deal with perceived injustice. Given the uncertainty in interpretation, the primary analysis in this thesis will be done only on the consent toward the U.S.

Another important measure of effectiveness is the "security" value. In PSOM, the security value represents the population's belief that they, their friends/family, and their property are safe from attack or other damage. Population security in PSOM is also a number from zero to ten, and also represents an internal value of negative infinity to infinity. A successful set of policies will result in high population security values for all population agents. If population agents of some factions have high security and agents of other factions have low security, it represents a failure of the peacekeeping force to protect all population factions.

2. Courses of Action

To attempt to determine best practices and test the outputs of the PSOM simulation, the author needed a varied set of courses of action (COAs). Five major choices were developed for the various forces, although, as described in Table 2, a hybrid set of actions was also simulated where the two sides used different levels of combat.

Table 2. Courses of actions and descriptions

Course of Action	**Purpose**
Withdraw	Modeling of forces not interacting with foes or population.
Protect	Modeling of forces not interacting with foes, but positively interacting with population.
Combat	Modeling of forces engaging in conventional combat.
Rampage	Modeling of forces attacking infrastructure.
Genocide	Modeling of forces attacking non-combatant population.
Combat/Genocide	A hybrid case using "Combat" case for Messiria and Fur while using the "Genocide" case for Rizeigat and Arab. Modeling one side using Genocide tactics while the other does not.

In the "withdraw" COA, each side would pull military forces back and not engage in combat. The purpose of this order set was to see how the Sudan Scenario would play out in the absence of actions by the various forces. It was a test of just population actions and background rules. In addition, the author wanted to see whether there were different results with military forces not engaged at all, versus a scenario where no military forces were fighting, but they were "showing the flag," protecting local population and infrastructure.

In the "protect" COA, forces are directed to provide humanitarian aid, patrol, and protect their population and infrastructure. The U.S./U.N. forces are given a similar task, although they are protecting the population and infrastructure for all factions. The purpose of this order set was to verify that units performing protective and humanitarian functions would have a positive impact. In theory, this should produce better outcomes than the "withdraw" order set.

In the "combat" COA, units are directed to either ambush any possible hostile forces, or engage in indirect fire attacks. The U.S./U.N. forces engage in

"protect/convoy," in order to reduce combat operations. Because engaging in combat requires picking a side, they "target" the Messiria and Fur factions in the order set used. This is the only order set that requires the U.S./U.N. forces to choose a side. It is possible that the "Clear" combat order should have been used instead of ambush for higher intensity combat, but in an insurgency with U.S. forces present, the ambush represents a lower risk option for the sort of irregular forces involved in an insurgency. The purpose of this order set was to model "conventional combat" between the opposing forces, without attempts being made at genocide or intentional damage to the infrastructure of hostile tribes.

In the "rampage" COA, units primarily attack the infrastructure of hostile tribal groups, although forces capable of indirect fire continue to do so. The U.S./U.N. forces try to protect all local infrastructure. The purpose of this order set is to represent irregular forces attacking hostile tribes to drive them out of an area, but stopping short of genocide.

In the "genocide" COA, tribal units intentionally attack the civilian population of hostile tribes. U.S./U.N. forces try to prevent genocide. This order set represents the worst-case scenario. In fact, when this was run, the scenario cut out before the full 50 turns because the population was reduced to less than zero in some grid squares, causing a program fault.

There was time for one more set of orders, so a combination named "genocide half" was run. In this order set, the Rizeigat and Arab faction units attacked the population of the Messiria and Fur ethnic groups, while the U.S., Messiria, and Fur tried to protect local populations from genocide. Messiria and Fur forces also made conventional attacks against the genocidal military forces.

3. Experiment Design

Of note, all experiments for this thesis used the SEED Center version of PSOM 2.6.2.3. Other versions of PSOM may have different results.

The objective of this thesis is to investigate the transient behavior of the measures of effectiveness over a large number of turns. In order to perform a detailed analysis, 10

items were chosen to vary, expected to be the most influential data inputs. These were the Rules of Engagement and Combat Firepower rating for each of the five sides being analyzed in the simulation, the U.S., Arab, Fur, Rizeigat, and Messeria. The ROE and FP variables were set to integers from 1 to 5 for the runs, these being all values allowed by PSOM.

A total of 513 design points varying the FP and ROE for each faction (see Appendix A) were run for each of the six COAs of Table 2. This comes from augmenting a 512-design point NOAB with the base case scenario. This gave a total of 3078 design points. Running the simulations took about 18 hours on the 40-core SEED Center cluster. Originally it was hoped to "mix and match" the different order sets, however with five factions and five order sets, we would have had to run all the combinations of the model 5^5 or 3125 times. Given that six runs (the five original order sets, plus one hybrid date set) took about 18 hours, fully saturating the combination space of order sets was infeasible. The simulation output is a table with 999691 rows and 27 columns showing the security value for each ethnic group, and the consent of each ethnic group toward each faction, on a scale of 0 to 10.

In addition to the large experiment described above, smaller experiments were conducted for other purposes. The first tests the importance of the stochastic mode by using 21 runs of the same scenario to see if results differ. The second tests the importance of the starting consent values by using six runs each of two scenarios with both +1/-1 difference from the starting values, and inputting the ending values of the first set of runs as starting values for the second set.

In addition to yielding the overall change in consent and security values from the beginning to the end of the simulation runs, the experiments provide detailed output of these measures at each turn. This allows an exploration of the time required for the scenario to settle out.

IV. DATA ANALYSIS

Previous analyses of PSOM have focused on discrete time results, showing the effect of a set of inputs at the end of some number of turns, however it is interesting to look at the changes over time. To do this, the data are put into the JMP statistical analysis software to analyze curves, both aggregate and discrete. An advantage of graphical analysis is that patterns can become more apparent when looked at visually. Also, a large number of data points can be looked at simultaneously, and in comparison to each other.

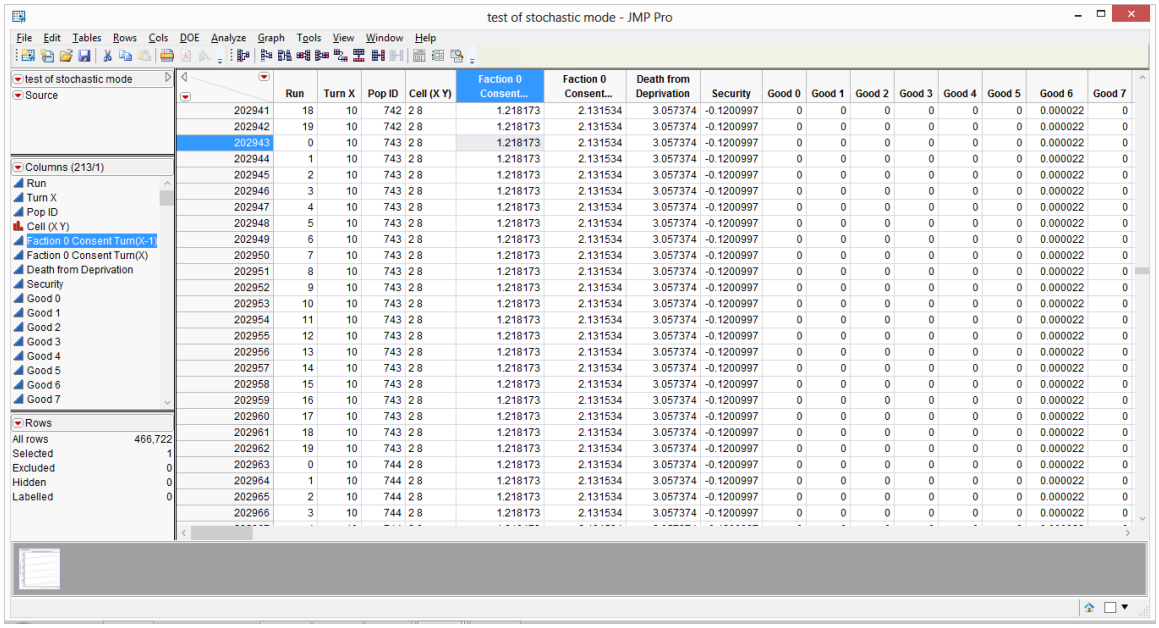
A. STOCHASTIC EFFECT TEST

If the primary output is going to be the value of consent toward certain groups, then the quality of consent outputs becomes very important. The PSOM literature available suggests that the effect of clicking the "Run in Stochastic Mode" button is minimal.[47] In order to determine to what extent the stochastic mode affects the consent output values, the withdraw course of action was run in batch mode for 20 turns (from turn 2 to turn 21). The batch run was 20 runs (0–19), using a stochastic seed of 635111537504469554. The reason the batch started with turn 2 was that turn 1 was used to set starting parameters, and I wanted to make sure these were not accidentally reset.

Surprisingly, as far as consent output was concerned, there was no effect. A snippet of the raw data shows this in Figure 2. Whether looking at run 1 or run 20, each item in each column is the same. This finding was confirmed using statistical functions in JMP and Excel.

[47] Marlin, "Ascertaining Validity in the Abstract Realm," 53.

Figure 2. Raw data from test of stochasticity of PSOM consent values



	Run	Turn X	Pop ID	Cell (X Y)	Faction 0 Consent...	Faction 0 Consent...	Death from Deprivation	Security	Good 0	Good 1	Good 2	Good 3	Good 4	Good 5	Good 6	Good 7
202941	18	10	742	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202942	19	10	742	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202943	0	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202944	1	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202945	2	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202946	3	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202947	4	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202948	5	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202949	6	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202950	7	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202951	8	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202952	9	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202953	10	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202954	11	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202955	12	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202956	13	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202957	14	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202958	15	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202959	16	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202960	17	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202961	18	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202962	19	10	743	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202963	0	10	744	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202964	1	10	744	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202965	2	10	744	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0
202966	3	10	744	2 8	1.218173	2.131534	3.057374	-0.1200997	0	0	0	0	0	0	0.000022	0

After looking at the results of the initial run and seeing that all the results were identical, I wanted to make sure that the batch run was not just re-using the starting seed for each run; which would result in 20 identical runs. The same scenario was run in batch mode using a different seed (035125298889949632). Because this was just determining the effect of adding a different seed to the final results, I used a single run to verify that it was not different from the original batch.

This suggested that stochastic mode would not affect my results, which greatly decreased the run time for the full experiments and subsequent analysis. However, the question immediately arises as to why stochastic mode is included if it does not have an effect. Well, it has an effect, but not on consent values.

To verify this, I ran my combat course of action in another batch of 20 runs of 20 turns (using a seed of 635381950076055390), and looked at the results of the "inter unit contact" for the first unit. The results are shown in Table 3.

Table 3. Combat losses from two different stochastic settings

Turn	Cell	Contact No	Att Contact Size	Def Unit Name	Def Contact Size	Def Stance	Att Deterrence Factor	Att Deterrence Roll	Att Casualties	Def Casualties
1	3 5	1	10	Mounted Squad 4	52.30708	Attack/Enforce - Clear	1	0.5539376	0	0.6552668
1	3 6	1	10	Mounted Squad 4	53.39589	Attack/Enforce - Clear	1	0.6130238	0	1.08881
1	3 7	1	10	Mounted Squad 4	55	Attack/Enforce - Clear	1	0.550519	0	1.09996
1	4 5	1	10	Mounted Squad 4	53.90004	Attack/Enforce - Clear	1	0.1637481	0	0.5041496
1	4 6	1	10	Mounted Squad 1	59	Control/Stabilise - Guard Resources	1	0.1740093	0	0.3035237
1	4 6	2	10	Mounted Squad 1	58.69648	Control/Stabilise - Guard Resources	1	0.1362866	0	0.3029689
1	4 6	3	10	Mounted Squad 1	58.39351	Control/Stabilise - Guard Resources	1	0.8935525	0	0.3024142
1	4 6	4	10	Mounted Squad 1	58.09109	Control/Stabilise - Guard Resources	1	0.0625357	0	0.3018597
1	4 7	1	10	Mounted Squad 4	51.65181	Attack/Enforce - Clear	1	0.9864367	0	1.076584
1	5 5	1	10	Mounted Squad 5	56.87943	Attack/Enforce - Clear	1	0.7346215	0	1.11291
1	5 6	1	10	Mounted Squad 5	58	Attack/Enforce - Clear	1	0.387695	0	1.120572
1	5 7	1	10	Mounted Squad 4	50.57523	Attack/Enforce - Clear	1	0.000355125	0	1.068984
Turn	Cell	Contact No	Att Contact Size	Def Unit Name	Def Contact Size	Def Stance	Att Deterrence Factor	Att Deterrence Roll	Att Casualties	Def Casualties
1	3 5	1	10	Mounted Squad 4	55	Attack/Enforce - Clear	1	0.5399455	0	0.6666425
1	3 6	1	10	Mounted Squad 4	50.08184	Attack/Enforce - Clear	1	0.5596483	0	1.065487
1	3 7	1	10	Mounted Squad 4	52.736	Attack/Enforce - Clear	1	0.4107186	0	1.084197
1	4 5	1	10	Mounted Squad 4	50.57522	Attack/Enforce - Clear	1	0.1404748	0	0.493377
1	4 6	1	10	Mounted Squad 4	53.23802	Attack/Enforce - Clear	1	0.05490083	0	0.502019
1	4 6	2	10	Mounted Squad 1	59	Control/Stabilise - Guard Resources	1	0.2852457	0	0.3035237
1	4 7	1	10	Mounted Squad 4	51.65181	Attack/Enforce - Clear	1	0.7106985	0	1.076584
1	5 5	1	10	Mounted Squad 4	54.33336	Attack/Enforce - Clear	1	0.9937957	0	1.095337
1	5 6	1	10	Mounted Squad 5	58	Attack/Enforce - Clear	1	0.3812512	0	1.120572
1	5 7	1	10	Tribe Group 1	30	Attack/Enforce - Ambush - Direct Fire	1	0.5764894	0	0.6665636
1	5 7	2	10	Tribe Group 1	30	Attack/Enforce - Ambush - Direct Fire	1	0.06855971	0	0.6665636

Note that Att means Attacker, and Def means Defender.

As you can see in Table 3, it was immediately clear that different combats were occurring, that different casualties were inflicted (the idea of 0.66 deaths or 0.303 deaths is interesting), and that the one recorded random number generation, "Att Deterrence Roll," was different. All of these conflicts were by Fur Large Squad 2 against various Rizeigat units.

The question then was, did those different casualties affect consent values? I pulled the consent values the same way as above, and again there were no differences between the results for the different runs.

B. INITIAL TRANSIENT ANALYSIS

This experiment design was intended to test whether in a given scenario and order set, there was a stable value. In theory, if the situation is not changing, the happiness (and thus consent) of the population should remain unchanged over time.

In order to test this, the initial consent values determined by the scenario designers were run for 50 turns, resulting in what appeared to be a stable value.

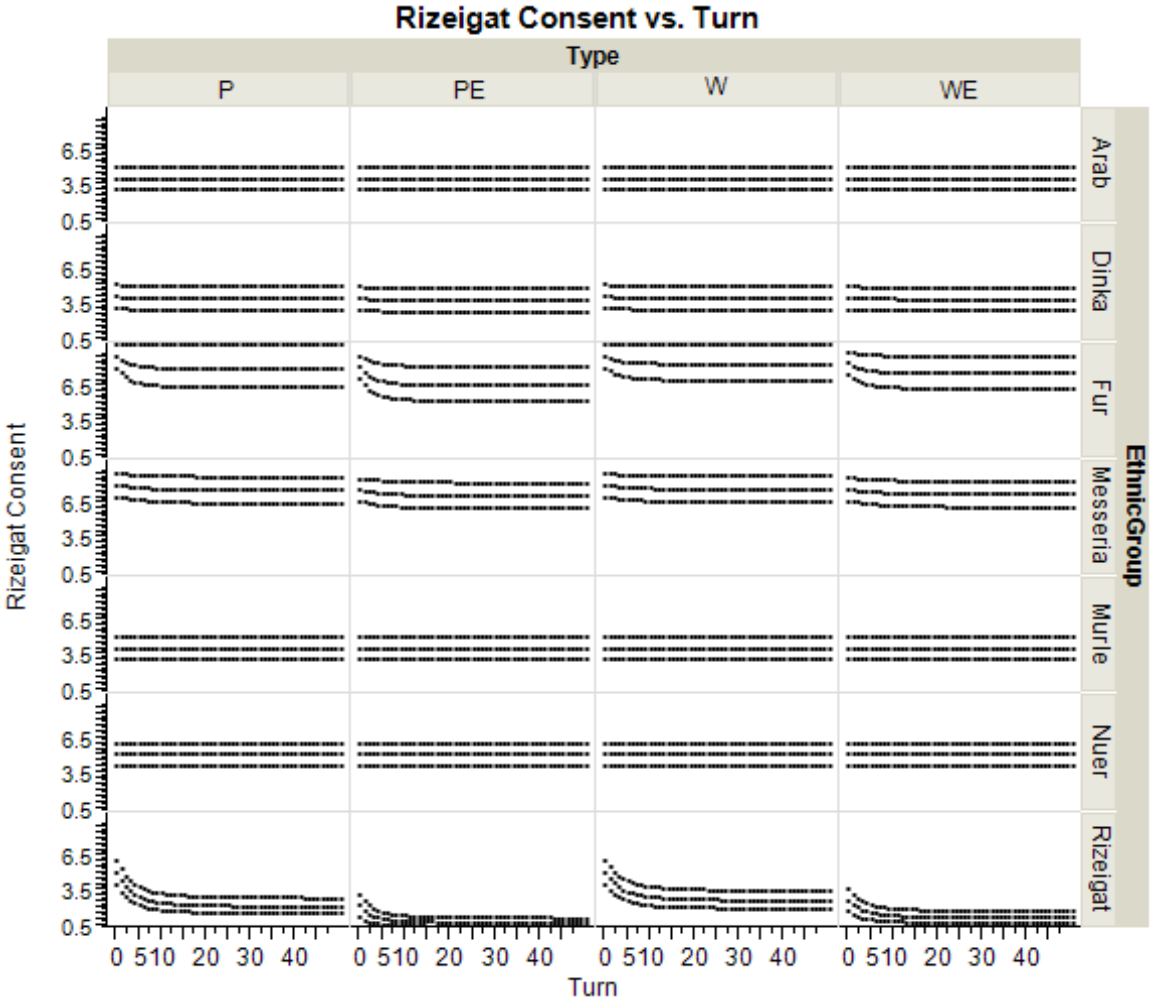
C. INITIAL VALUE SENSITIVITY ANALYSIS

There were a few interesting questions involved in the determination of a final stable value, both related to how variations in the starting value would affect the final value. One is how a limited, defined change in the initial value would change the final consent value, and the other was how stable the final value would be if fed back into the simulation and run again. In theory, if there were a stable value, then feeding the stable value in as a starting consent value should result in no change.

Two scenarios were chosen to develop these baseline numbers and test them. In one all sides protected their own population—the "protect" scenario. In another all military forces withdrew from combat entirely—the "withdraw" scenario. The initial values for consent were drawn from what the original scenario designers input. To test how sensitive to defined changes in initial values these numbers were, they were varied by exactly one point up and down. The simulations were run with these three sets of input consent values and these two scenarios for 50 turns, and the final values were determined. These show as the three sets of lines under "P" and "W" (for patrol and withdraw scenarios) in Figure 3.

While the changes clearly dropped off with time, the question remained as to whether the consent values were converging toward approaching a natural (steady state) value, or whether the effects of the unit actions were decreasing over time, i.e., "what have you done for me lately." The original starting value resulted in certain final values, and these were fed back into the scenario, again with an increase and decrease by one, which show in Figure 3 under "PE" and "WE." These results were very useful in determining the nature of the increase.

Figure 3. Rizeigat consent toward other factions by scenario



As you can see by the graphs in Figure 3, what at first appears to be a reversion to a mean is not. Re-inputting the value after 50 turns as a new starting value did not result in a steady state at the value it had settled into in the prior simulation, but instead the value dropped again in approximately the same way.

In Figure 3, the clearest changes are for the Fur, Messeria, and Rizeigat consent values. Table 4 shows these results, with the consent change observed over 50 turns shown in the rightmost column.

It is worth noting that while the ending values (for scenario P and W) were plugged into the model to create new starting values (for scenario PE and WE), there is

not an exact match. For example, the W scenario ending value was 5–2.432659 or 2.567341, but the starting value for the WE scenario was 2.617273. When I went back to the starting data, there were small changes between the ending value of the original scenario, and the starting value fed into the second set (PE and WE). This may be related to the difference between starting at turn 1 or turn 2, but it does not appear to cause any change in the conclusions that can be drawn from the results.

Table 4. Rizeigat population consent changes toward each faction by scenario

Type	Case	Faction	Start	End	Change
P	Base	Fur	7	5.27644	1.723556
PE	Base	Fur	5.34181	3.54426	1.797548
W	Base	Fur	7	5.68103	1.318974
WE	Base	Fur	5.73013	4.30721	1.422916
P	MinusOne	Fur	6	4.17954	1.820458
PE	MinusOne	Fur	4.34181	2.68666	1.655146
W	MinusOne	Fur	6	4.58162	1.418377
WE	MinusOne	Fur	4.73013	3.36015	1.369979
P	PlusOne	Fur	8	6.56943	1.430571
PE	PlusOne	Fur	6.34181	4.53541	1.806395
W	PlusOne	Fur	8	6.92774	1.072265
WE	PlusOne	Fur	6.73013	5.37124	1.35889
P	Base	Messeria	8	5.44818	2.551821
PE	Base	Messeria	5.61725	2.77206	2.845195
W	Base	Messeria	8	6.10054	1.899458
WE	Base	Messeria	6.21987	3.91571	2.304163
P	MinusOne	Messeria	7	4.11131	2.888694
PE	MinusOne	Messeria	4.61725	2.04257	2.574687
W	MinusOne	Messeria	7	4.77144	2.228565
WE	MinusOne	Messeria	5.21987	2.99296	2.226911
P	PlusOne	Messeria	9	7.29227	1.707725
PE	PlusOne	Messeria	6.61725	3.69223	2.925027
W	PlusOne	Messeria	9	7.78764	1.212356
WE	PlusOne	Messeria	7.21987	5.03904	2.180832
P	Base	Rizeigat	5	2.04769	2.952305
PE	Base	Rizeigat	2.09959	0.64029	1.459304
W	Base	Rizeigat	5	2.56734	2.432659
WE	Base	Rizeigat	2.61727	1.09067	1.526603
P	MinusOne	Rizeigat	4	1.46509	2.534909
PE	MinusOne	Rizeigat	1.09959	0.30815	0.79144
W	MinusOne	Rizeigat	4	1.87166	2.128344
WE	MinusOne	Rizeigat	1.61727	0.62452	0.992756
P	PlusOne	Rizeigat	6	2.78598	3.214015
PE	PlusOne	Rizeigat	3.09959	1.03647	2.063121
W	PlusOne	Rizeigat	6	3.41282	2.587179
WE	PlusOne	Rizeigat	3.61727	1.63676	1.980511

The author had also considered the possibility that the change in consent values would be stable; however, these data also show this not to be the case. The original reduction in consent of the Rizeigat in the withdraw scenario with base starting consent was from 5 to 2.56, a reduction of 2.43, but the reduction from 2.61 was only to 1.09, a drop of only 1.52. However, what is verifiable and significant is that as the starting consent value approaches 6 from above or below, the change in consent is maximized.

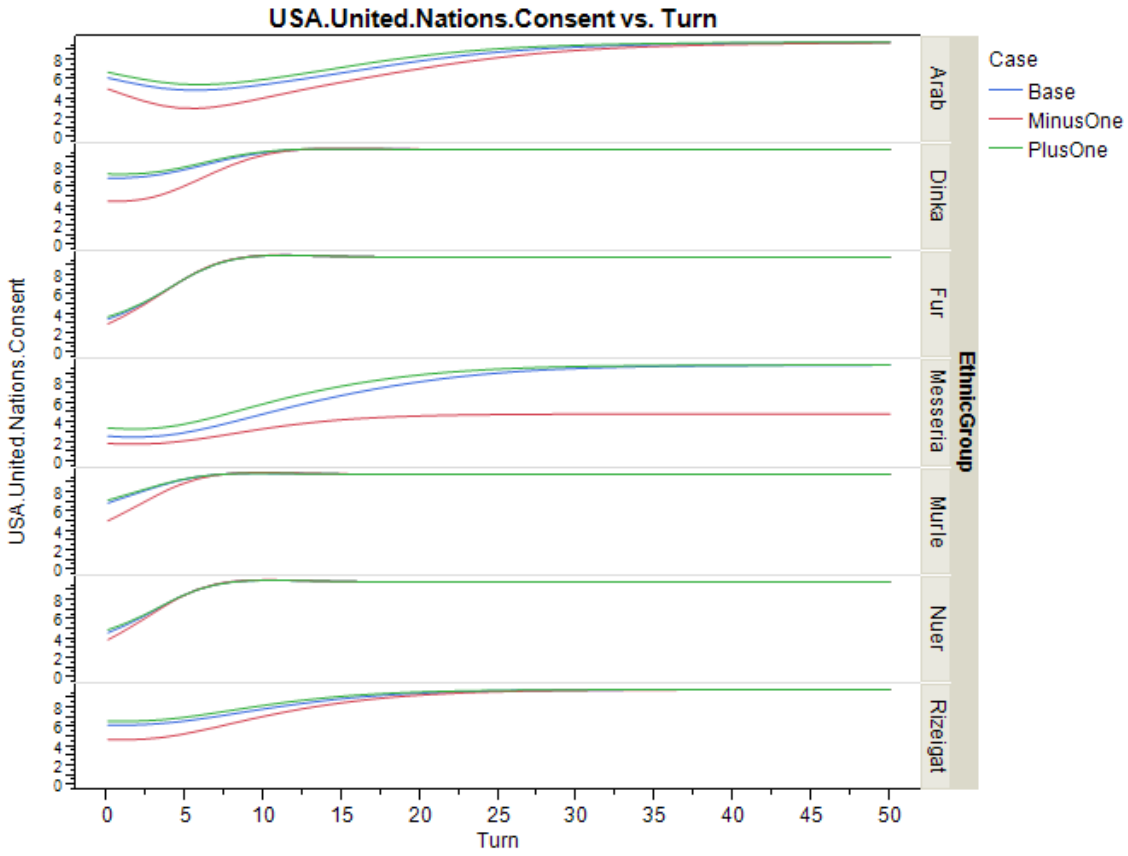
Since the reason for the above analysis was to help future users of PSOM chose optimal starting consent values, and understand what the changes during the simulation were for, the author decided to seek input from the designers of the program. An email forwarded to the author from Nathan Hanley, one of the creators of PSOM, describes how one of two methods can be used to set the starting security values.[48] The first is to use code or the GUI to directly set the starting values. The other is to "Run to Equilibrium" which is essentially what was demonstrated with consent above. According to an email from another expert on the program, Stephen Upton,[49] the parameter is not initially set, but is calculated based on casualties incurred.

Another important consideration was how the initial consent values affected the results. While the simulation determined changes to inputs each turn, the initial values were based on the considered judgment of subject matter experts. Looking at the output as a graph by turn gave a distinct nonlinear indication. It appeared that the consent values were converging to a specific value (different for each combination of two factions). In the case of the U.S. that mean was approaching 10 (maximum consent), as shown in Figure 4. Note that Figure 4 was created using all combinations of the inputs used to make Table 4.

[48] Nathan Hanley, email message to author, June 25, 2013.

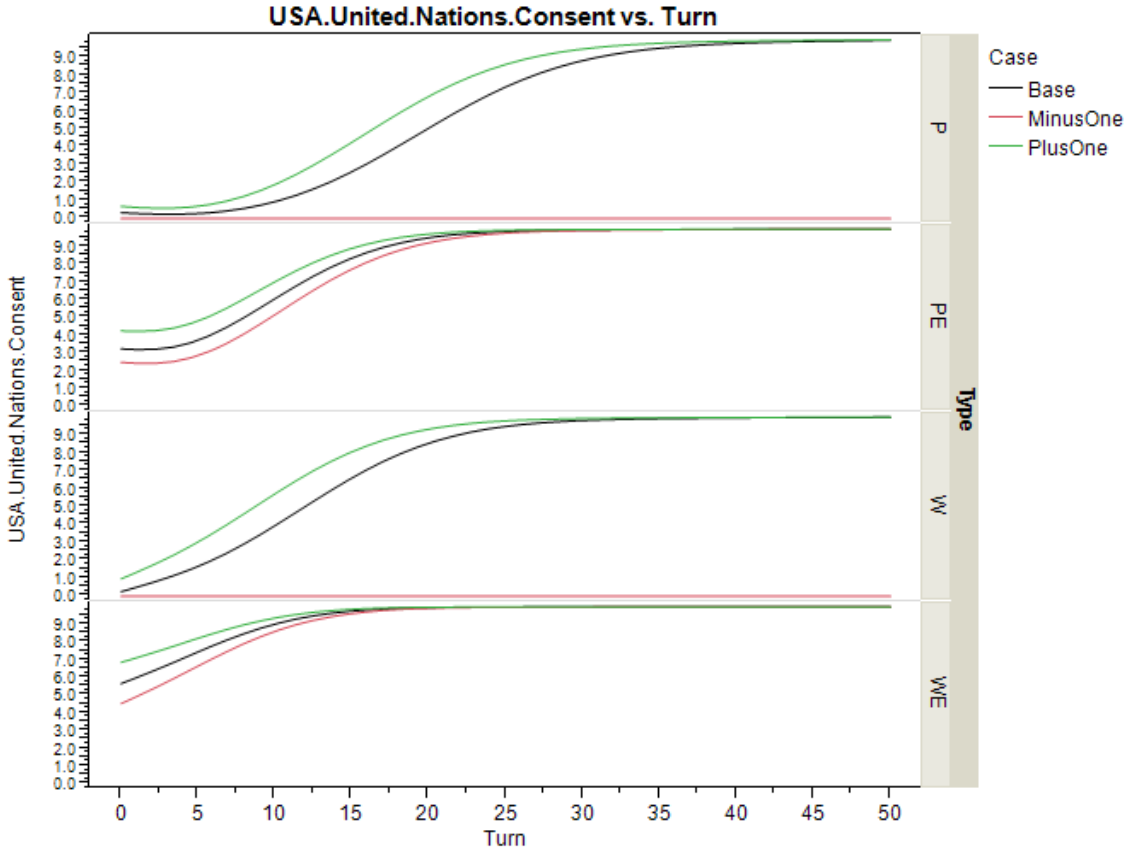
[49] Stephen Upton, email message to author, April 17, 2013.

Figure 4. Variations in consent toward U.S. based on initial values



In the above experiment, the initial values were varied by increasing or decreasing all values by 1. This led to at least one interesting result that needs to be watched for in future analysis. The Messeria tribal consent toward the U.S. is the one group that did not uniformly increase toward 10, The two trials where the consent was unchanged or increased did go to 10, but the trial where the starting consent was reduced by 1 led to an ending consent of 5. Digging into the source of this result gives us Figure 5.

Figure 5. Messeria tribe consent toward the U.S. by turn, sorted by initial consent and scenario type



Because the scenarios tended towards final values, it seemed valuable to run the scenarios for 50 turns to develop those values, and feed them back in as initial values. Because the U.S. consent invariably tended towards 10, this meant that the PE and WE scenarios had starting consent towards the U.S. of 10. The original scenarios had much lower consent values, and after subtracting 1 from them, the values became 0. In both the "P" and "W" scenario, this was the case, and the Messeria consent towards the U.S. started at 0 and barely increased.

Table 5. Consent change by scenario type and starting consent

Type	Case	Faction	Start	End	Change
P	Base	U.S.	1	9.9413433	8.9413433
P	MinusOne	U.S.	0	**0.0000005**	0.0000005
P	PlusOne	U.S.	2	9.9730038	7.9730038
PE	Base	U.S.	6.63812	9.9969198	3.3588039
PE	MinusOne	U.S.	5.63812	9.9953132	4.3571974
PE	PlusOne	U.S.	7.63812	9.9980861	2.3599702
W	Base	U.S.	1	9.9887912	8.9887912
W	MinusOne	U.S.	0	**0.0000026**	0.0000026
W	PlusOne	U.S.	2	9.9948965	7.9948965
WE	Base	U.S.	6.66123	9.999431	3.3382009
WE	MinusOne	U.S.	5.66123	9.9991445	4.3379144
WE	PlusOne	U.S.	7.66123	9.9996464	2.3384164

Note: end values near zero are highlighted and bold.

I strongly recommend that in the future, researchers exploring variations on initial consent use a percentage of current value, or use 0.1 as a floor value instead of 0, to prevent this problem. In a conversation with Stephen Upton, Mary McDonald, and Nathan Hanley, experts familiar with the internal workings of PSOM, it was revealed that the program converts the initial 0–10 scale into a nonlinear scale (–infinity to +infinity), with the result that a starting value of 0 cannot be moved significantly towards a higher number.

Inputting a 10 into the starting value may not result in the same problem. In the WE scenario, the Dinka consent towards the U.S. started at 10, dropped to 9.999996212, and then went back up to 10. Also, while consent toward a faction has been observed dropping to 0 in visual displays, it would be difficult for it to be truly zero on the scale, so it would still be able to move back up with proper inputs. It appears that only a hard-coded zero causes this problem.

Figure 6 shows that the consent levels move towards a steady state over time. The curve changes rapidly at first, and then slows down as the steady state is approached, which resembles a quadratic curve or (inverse) logarithmic curve.

Figure 6. Consent toward different factions smoothed lines

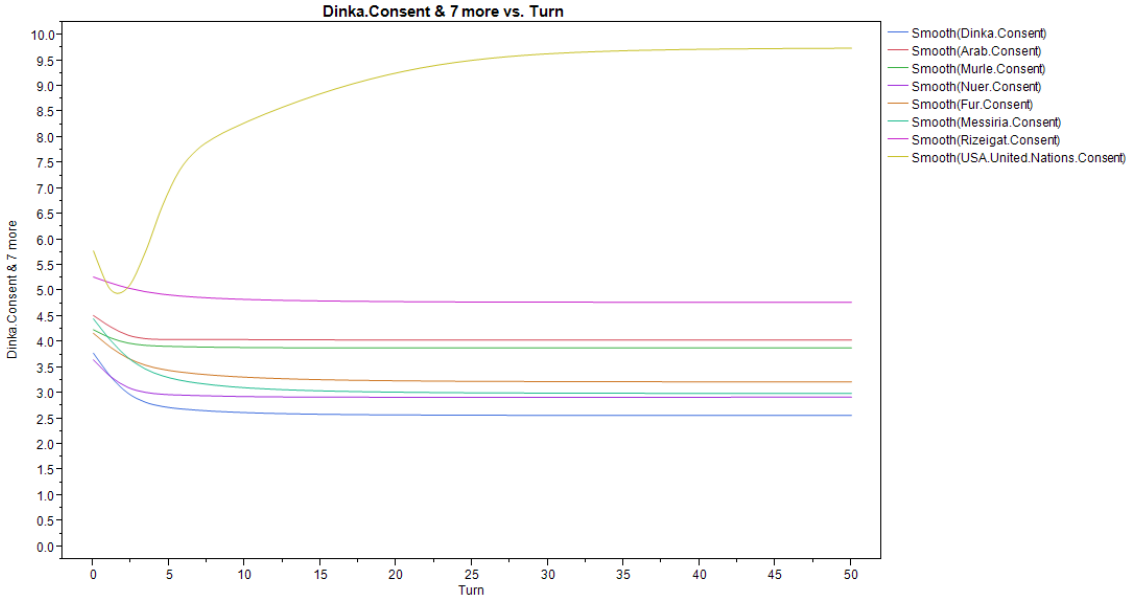
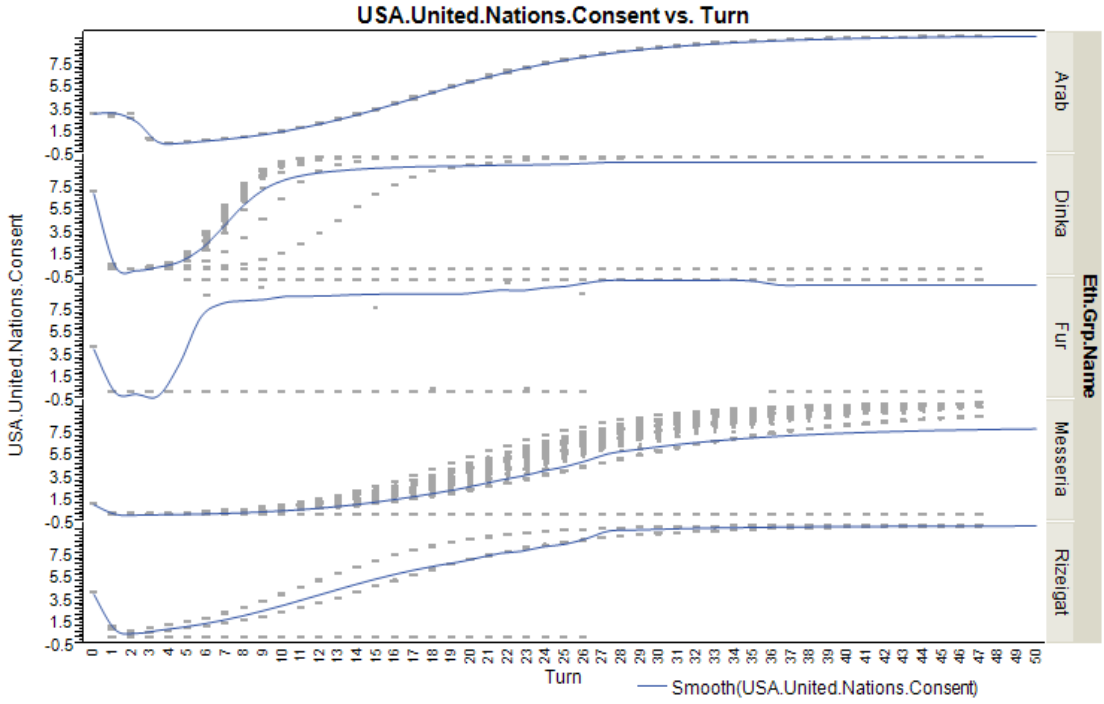
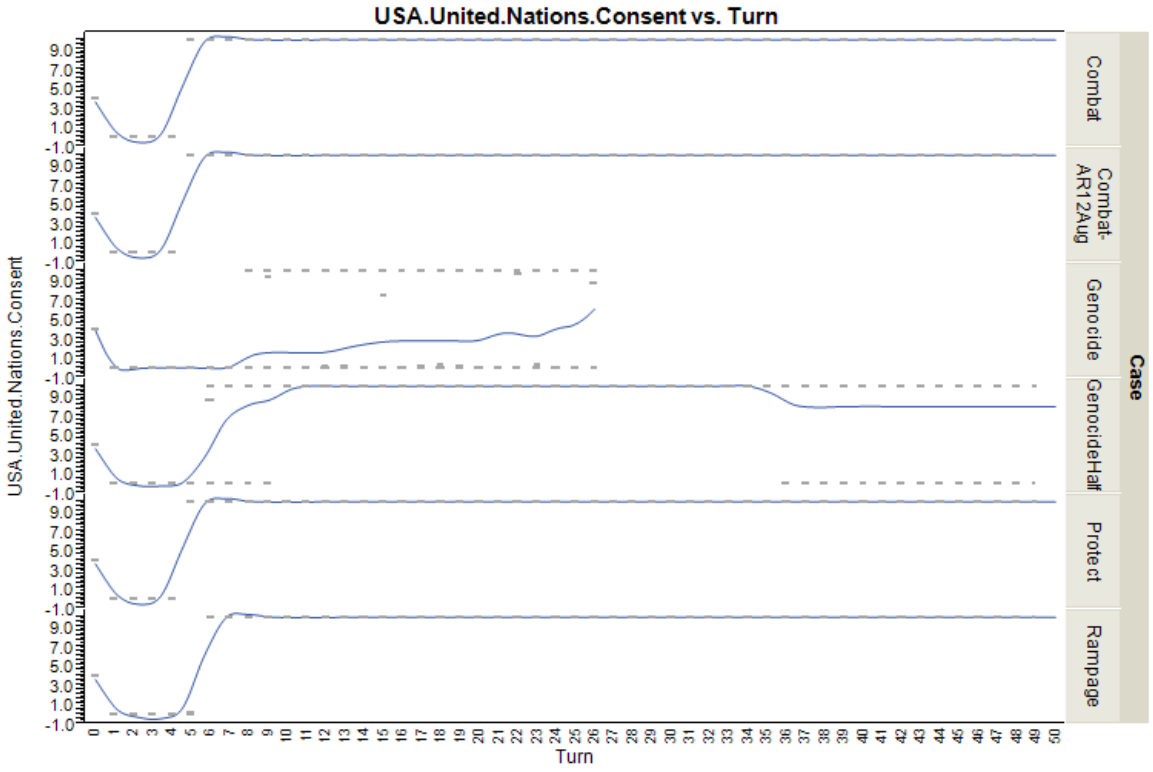


Figure 7. Consent toward U.S. by faction, actual data points



Looking at Figure 7, almost all Arab data points are on a single line. The Dinka have a number of quadratic lines, and at least one set of points at zero, the Messeria fill all area below a quadratic line, and the Rizeigat are a simpler version of the Dinka. However, the behavior of the Fur is especially interesting. To look at it more closely, see Figure 8.

Figure 8. Consent toward U.S. by Fur, and smoothed consent values, for the 513 different simulated scenarios

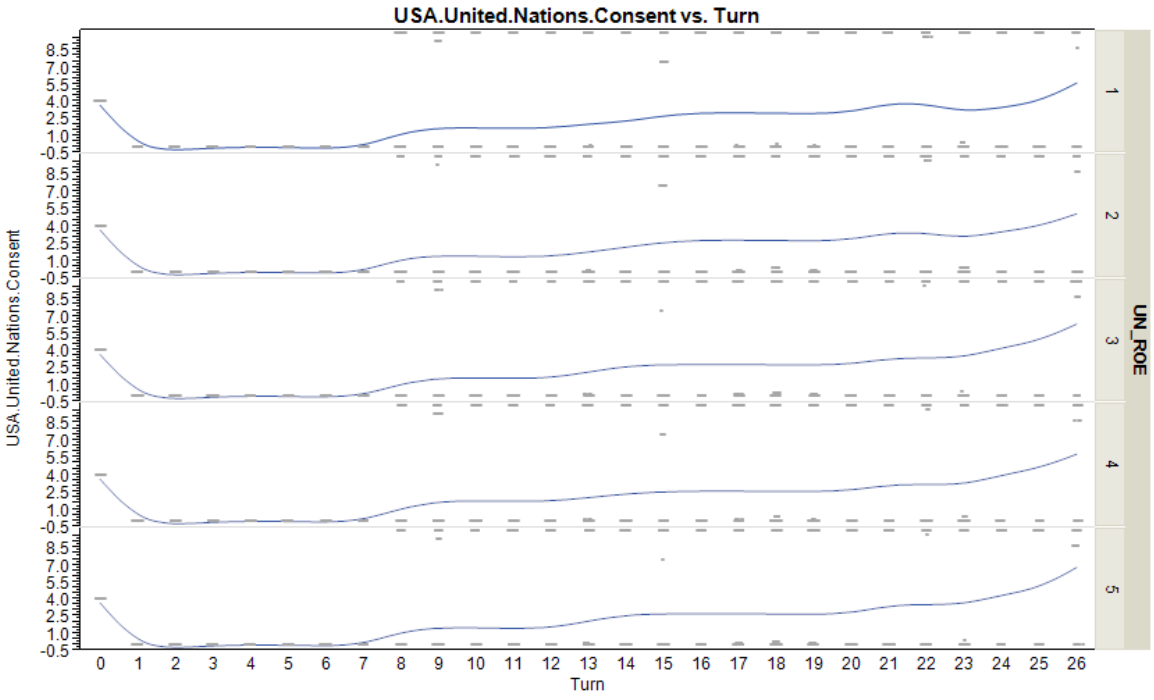


In most of the scenarios, the line drops to zero, then rises to 10, seemingly skipping the intermediate consent values. But the behavior of the Genocide and Half Genocide (Rizeigat and Arab factions committing Genocide against the Fur and Messiria), you see even odder behavior. In some scenarios, the consent value is ten, and in other combinations of ROE, Force Protection, etc., the consent value is zero! This sometimes causes the smooth line to show in places other than zero or ten, but the vast majority of consent values reported are at one of the extremes.

However, the use of the smoothing line has value, as it gives a visual indication of how many of the consent values are at ten vs how many are zero.

Looking at the results by U.S. ROE (see Figure 9) and Force Protection did not fully explain the results. Clearly, there are some differences: the higher the U.S. ROE, the more consent ticks upwards. In this particular case, this means that populations suddenly switch from hating the U.S. to totally trusting the U.S. forces (note that despite the smooth line slowly rising, the data points are almost always either at zero or at ten).

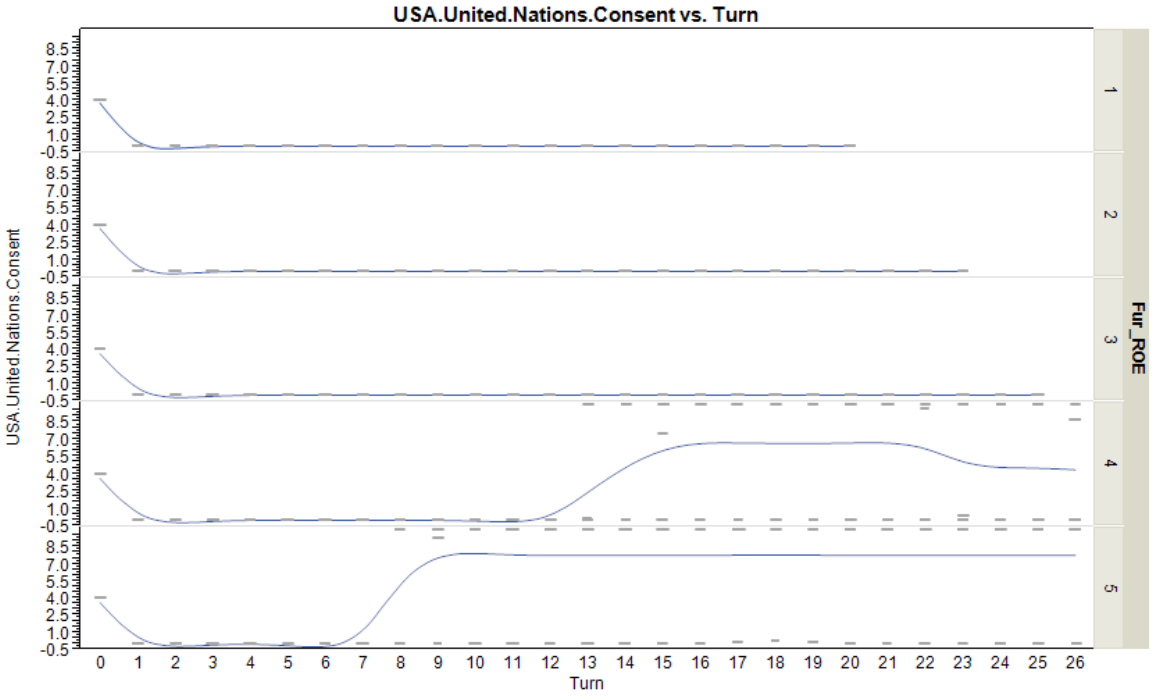
Figure 9. Fur consent toward U.S. by U.S. ROE (with smoothed line)



It is worth mentioning that the reason that the Genocide scenario does not go to 50 turns is that at 27 turns some population values, in some of the test runs, went negative (different genocide scenario test runs did this on different turns). This meant that the population of at least one ethnic group in one region was completely wiped out. This did not happen in the Half-Genocide scenario, so it was probably an Arab or Rizeigat population that was destroyed, but it reveals how much the populations can be affected. Is it possible that the population is being reduced to a number that the U.S. is better able to

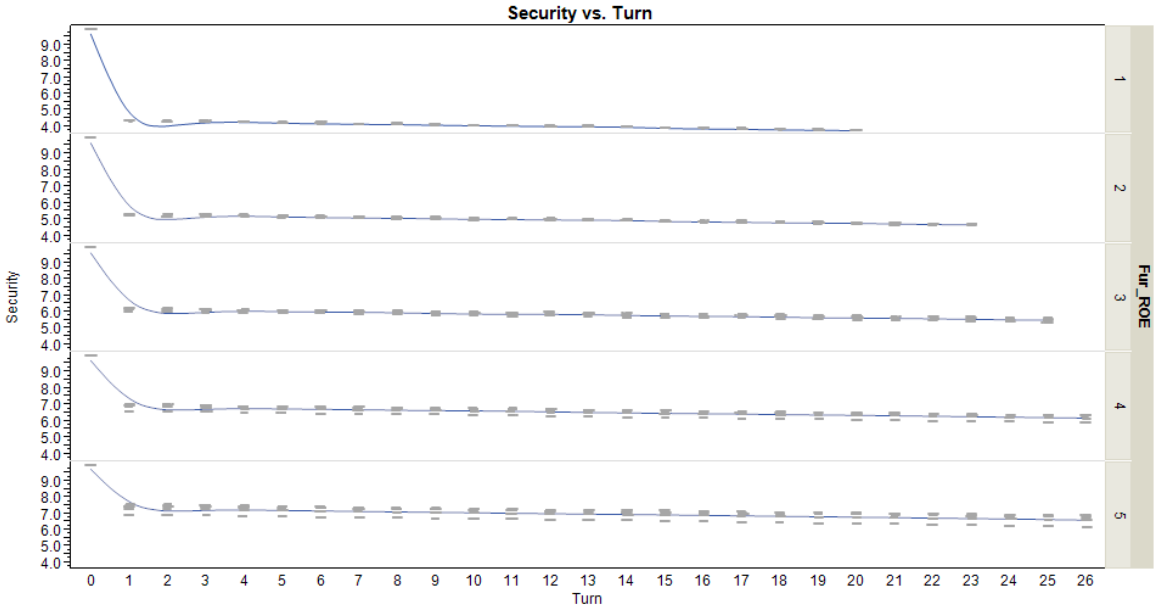
protect? If you look at the Fur ROE, you can see that it strongly affects the consent value (Figure 10).

Figure 10. Fur consent toward U.S. based on Fur ROE (with smoothed line)



As you can see, a low Fur ROE leads to low U.S. consent, which is probably driven by a lack of perceived security, as shown in Figure 11.

Figure 11. Security of Fur population in genocide scenario by Fur ROE (with smoothed line)



So the stronger the Fur response, the more secure their population feels. I do not know for sure if this is because a stronger Fur response is more visible to the population, or more effective. However, if you look at the lower numbers for Fur response, you will see that the scenario does not run for as many turns, which indicates the complete depopulation of at least one area by the genocide (as discussed earlier, when the population reached zero and further genocide was ordered, it created a negative value fault that ended the run). In the areas with higher Fur response, the simulation continued, which suggests that the units were considered to have actually been more effective at protecting the population, not just looking good to the locals.

Note that the number of rows is not an even multiple of the design points. Some runs terminated early due to genocide reducing population numbers to negative values, also see next paragraph.

In order to run parallel plots of the data, the consent and security values of the initial turn were subtracted from turn 20 to produce a difference. This revealed something disturbing about the data. While every design point had output for the initial turn, some design points were missing output from the 20th turn. Specifically, design points 317 and

476 of the combat AR COA, 391 of the half genocide COA, and design points 10, 75, 76, 101, 202, 282, 311, 317, 318, 350, 351, and 358 for the protect COA. This is different from the early termination of Genocide runs, and merits further investigation in the future.

The design points with partially incomplete output and the associated starting FP and ROE values, taken from Appendix A, are listed in Table 6.

Table 6. Design points with partially incomplete output in NOAB set of simulations

Cases	DP	UN_ROE	UN_FP	Rizeigat_F	Rizeigat_F	Messiria_I	Messiria_I	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
Protect	10	4	5	3	4	1	2	1	3	1	2
Protect	75	1	3	1	1	5	4	1	3	3	1
Protect	76	1	5	3	5	4	2	1	4	5	1
Protect	101	1	4	1	2	5	4	3	4	4	5
Protect	202	3	2	5	2	4	2	2	2	4	5
Protect	282	1	5	1	1	4	3	1	3	3	1
Protect	311	2	3	3	2	5	4	3	4	2	1
Prot/Com AR	317	5	1	5	1	1	2	4	3	1	4
Protect	318	5	3	3	5	1	1	4	3	5	5
Protect	350	1	5	5	3	4	5	5	5	4	4
Protect	351	5	3	1	2	3	1	2	3	3	2
Protect	358	3	1	1	4	2	2	1	1	2	1
Genocide Half	391	2	3	2	2	2	5	2	5	1	2
Combat AR	476	3	1	2	2	2	4	5	5	3	3

There does not seem to be a pattern to the missing data. Looking at the original data set, while turn 0 had 21546 lines of data, turns 1–20 only had 21441, turns 21–23 had 20650, turns 24 and 25 had 19873, turn 26 had 19229, and all remaining turns had only 17850 lines of data. Likewise, there should have been identical numbers of data points for each case (COA), however while combat and rampage had 183,141 lines of data, combat AR only had 182,441, genocide half had 182,791, protect 178,941, and genocide only 89,236.

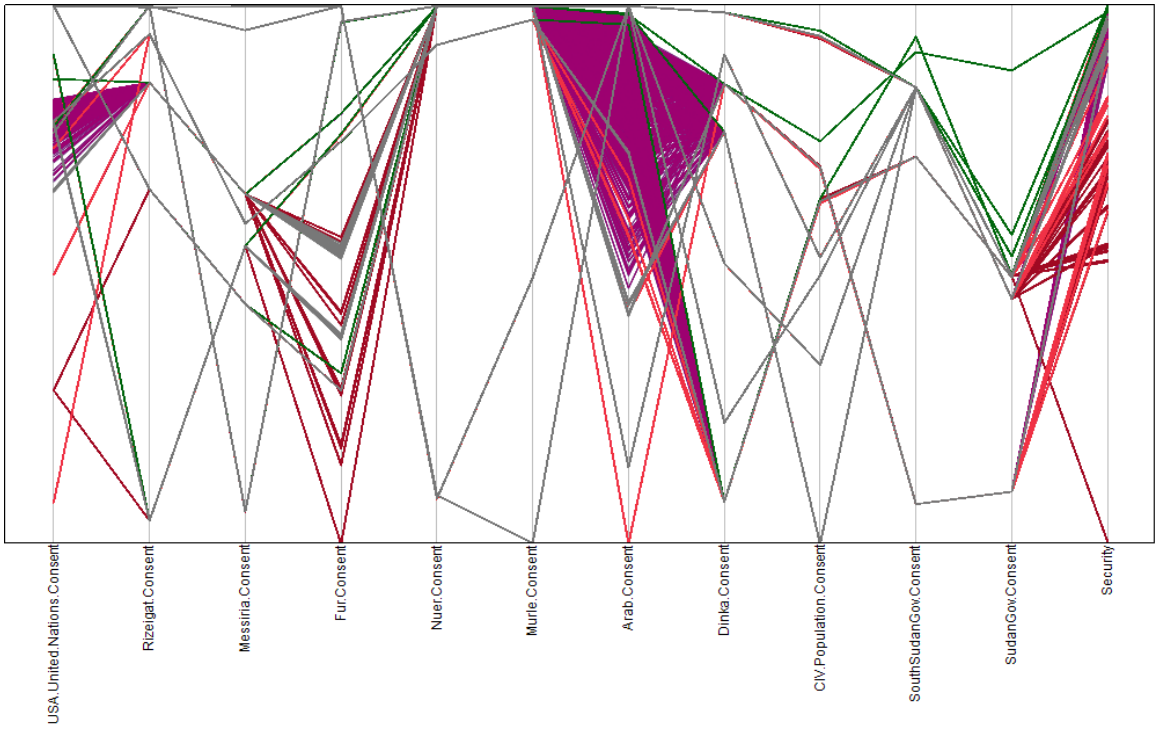
D. OUTPUT ANALYSIS

A parallel plot, such as that in Figure 12, can provide additional insights about the output of the runs. A parallel plot displays one line for each run, and shows several result values using that line. By having several lines, you can compare multiple result values by

comparing the lines, which can uncover information about relationships that otherwise would be hard to perceive.

In Figure 12, the change in consent and security values between turn 20 and the initial value is shown for the full 513 design-point set. Note that since the value is "final minus initial," lines at the top represent an improvement and lines at the bottom represent the value getting worse. To make the plot more informative, the six starting scenarios are color-coded. What is interesting is that most of the results fall into narrow bands, suggesting that a small change in force protection or ROE does not create a large change in output. Instead, the increases tend to be for the same amount for many different input values. The exception is the AR Combat scenario's effect on the U.S. and Arab consent.

Figure 12. Parallel plot of consent and security values by case

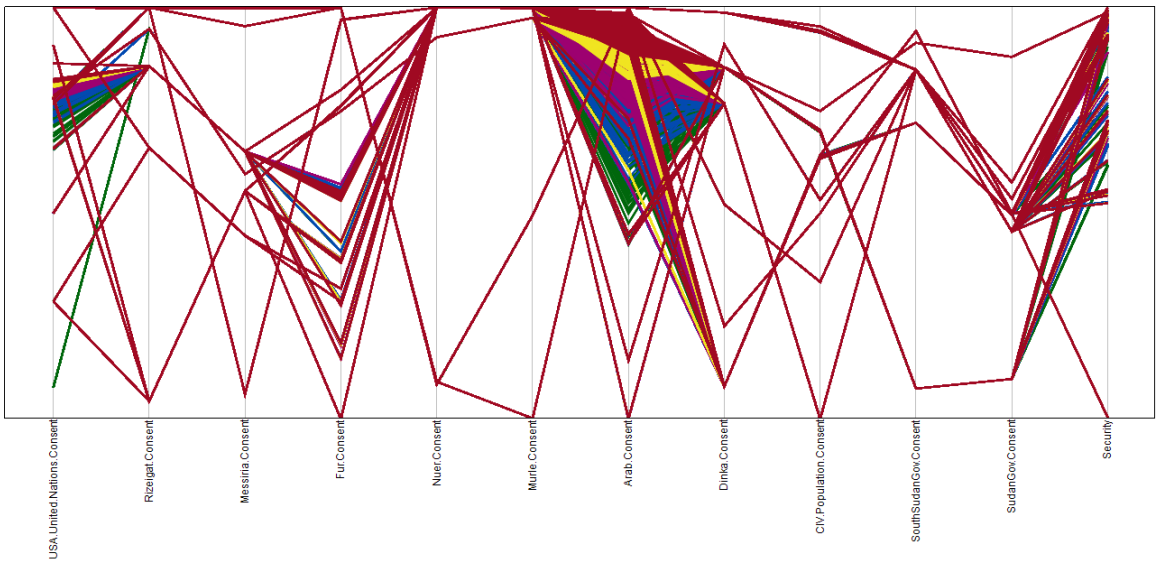


Colors by case: Protect Green, Genocide Red, Half Genocide Pink, Rampage Gray, Combat Blue, Combat AR Purple

Figure 13 shows the same parallel plot of consent changes, but this version has colors by Arab ROE. As you can see, the Arab ROE has an explanatory effect on the

Arab consent value. Note that the red color is displayed last, so it is covering much of the green, blue, purple, and yellow results.

Figure 13. Parallel plot of consent changes by Arab ROE



Graph colors are Green for ROE 1, Blue for ROE 2, Purple for ROE 3, Yellow for ROE 4, and Red for ROE 5. Note that ROE 5 was displayed last and is covering some of the lines of other colors.

Note that color coding the ROE on the parallel plots makes them much more informative. Alternatively, taking subsets of the data would allow specific ROEs to be considered in more detail. A similar plot of U.N. ROE did not result in useful information; the data points for the last ROE covered mostly the same points as the other ROE settings. Similarly, U.N. FP did not yield useful information in a parallel plot.

E. STABLE VALUE IDENTIFICATION

So if changes to consent values gradually approach a mean and stay there, how long does the system have to run to effectively reach the stable value? In other words, at what point does running the scenario cost resources that provide no new information of value? By running the Rampage scenario for 100 turns, I was able to get 8217 (1161 population units times seven faction consent values each) columns of data.

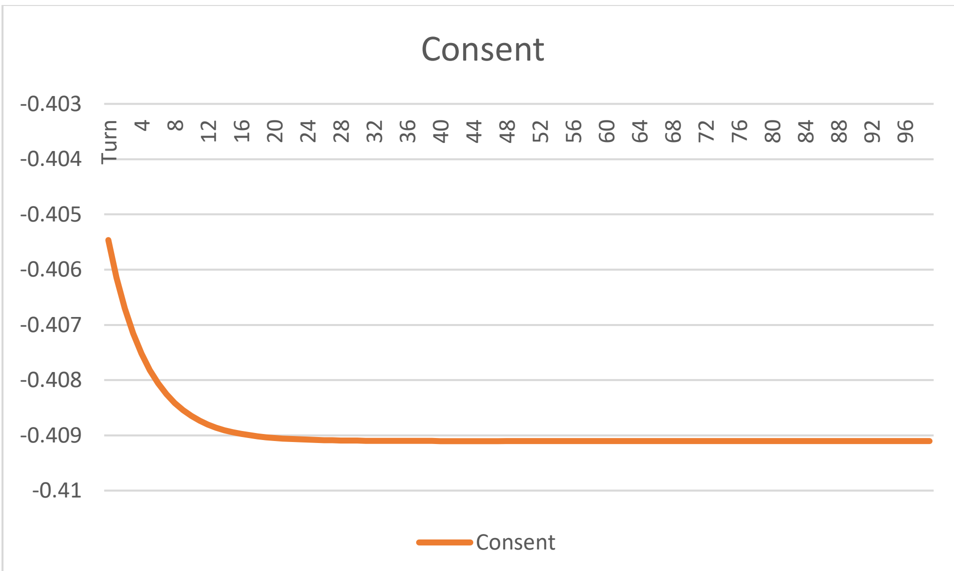
MSER (short for mean squared error reduction, or (minimum) mean squared error rule) is a method of finding the initial run needed for output data to stabilize before running experiments.[50] PSOM consent values, like many other statistical values that change over time, can be affected by the starting value. Using a MSER analysis can find out how many time elements it takes for this effect to diminish to near zero. MSER works by starting at the end of a data set (in this case, turn 100) where the data are assumed to be in steady state. It steps back through the data, adding earlier turns to the "included" set until such inclusion results in a sufficiently large increase in the mean square error estimate. Professor Paul Sanchez provided a ruby program called mser.rb that applies MSER to one or more output files, and can be used to construct a confidence interval for the mean response. The mser.rb program provides a number of turns to keep, but we want to find out the number of turns to discard, which we can call turn_s (for stable point). As an example, Table 7 shows the result from a single column, and Figure 14 is a graph of the corresponding consent values. The results from mser.rb are x-bar = -0.409100 and n = 70, so the chosen truncation value for this run is turn_s = 100–70 = 30. Although the overall magnitude of the change is small (less than 1% of the stable value), the fact that there is zero change in consent beginning with turn 31 means that MSER is able to distinguish very minor differences, and truncate appropriately at turn_s = 30.

[50] Paul J. Sánchez and K. Preston White, Jr., "Interval Estimation Using Replication/Deletion and MSER Truncation," in *Proceedings of the 2011 Winter Simulation Conference*, ed. Sanjay Jain et al. (Piscataway, NJ: IEEE Press488.

Table 7. Sample of consent values that stabilize quickly

-0.40547	-0.40615	-0.4067	-0.40715	-0.40752	-0.40782	-0.40806	-0.40825	-0.40841	-0.40854
-0.40865	-0.40873	-0.4088	-0.40886	-0.40891	-0.40894	-0.40897	-0.409	-0.40902	-0.40903
-0.40905	-0.40906	-0.40907	-0.40907	-0.40908	-0.40908	-0.40909	-0.40909	-0.40909	-0.40909
-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091
-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091
-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091
-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091
-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091
-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091
-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091	-0.4091

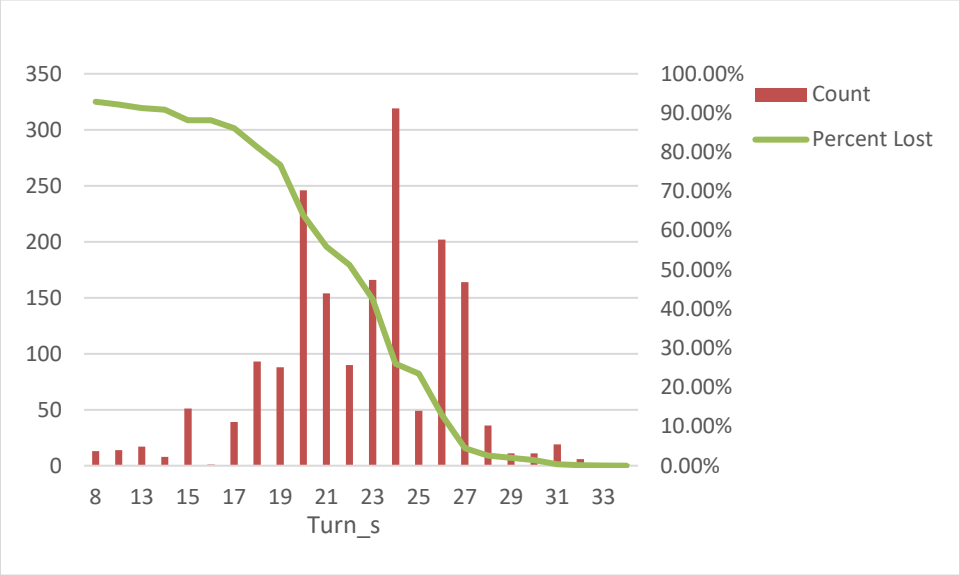
Figure 14. Graph of consent values that stabilize quickly



Looking at the detailed data, a number of design points yield results that are either actually or effectively unchanging by the end of the simulation. 258 columns of data were filled with nothing but zeros, clearly, they were already settled. Another 5946 of the 8127 columns had no variation in the consent value (it was the same number each turn for the entire simulation). If you remove the consent values that were 0 or did not change over the 100 turns the scenario was run, you are left with 1,923 consent values that did change over time, and these show an average turn_s value of 22.49 with a standard deviation of only 5.30. Figure 15 shows the counts for the number of columns associated with each

turn_s truncation value, and what percentage of population units' faction consent values would not be in stable settings if you used that turn_s. As you can see, even turns 26 and 27 have a lot of data points, but by turn 30, you have almost certainly reached the stable value.

Figure 15. Graph of MSER results



V. CONCLUSION

PSOM and other peacekeeping/population influence programs provide something traditional wargames do not. As the Anbar Awakening showed us, winning the hearts and minds of the locals is the true path to victory in an insurgency or ethnic conflict. Models for the attitudes of the local population, for how our actions affected the local population, and their perception of our forces, help us choose the strategies that can win the war, as opposed to battles. A battle that kills a thousand foes, and creates five thousand, is not a victory no matter how one-sided our casualties are. But with PSOM we can win the victories of infrastructure repair, rebuilding cities, making the population feel that their society is just, safe, and that they are being listened to. This is how we win a lasting peace.

But while PSOM can be beneficial for a military planner either evaluating a future area of operations, or seeking to develop a training simulation for officers and leaders, there are a number of issues that analysts should be aware of when using the simulation. Thought should be put into determining the starting values of consent, initial population feelings about how secure they are, and even such questions as how large map grid squares should be. It is also important to note that changes in consent drop off by time, showing a "what have you done for me lately" effect.

Consent values in the simulation are displayed from zero to ten, but represent an internal nonlinear scale from negative infinity to infinity. Because of this, the change in consent, or the percent change in consent, may be better indicators of whether a plan was successful in achieving the desired goals than the numerical consent value at the end of the simulation. This also means that there is no need to expend major resources getting an exact idea of how different groups feel about the actors in a conflict. A good guess is just as useful, allowing you to see how different strategies might affect the safety and goodwill of the local population. There is one important caveat. When setting initial consent for a training simulation, setting an area or even an ethnic group to zero consent could be problematic, as any group that has zero consent will never gain consent, however, for the same reason, this should not be used for a real world based simulation.

While there is a stochastic mode in PSOM, it affects combat values, not population responses. This means that while a mixed simulation (attempting to suppress an opposition/insurgent group through force of arms while depriving them of local support), might be worth running in stochastic mode and using multiple runs, if your primary measures of effectiveness are security or consent values, you can save time and effort by running PSOM in normal mode instead of stochastic mode.

Also, by using MSER, it was determined that if the stances and combat modifiers are not changed for about 30 turns, the consent values will reach an equilibrium point. This can be useful in a few ways: First, it can be used to set starting consent values for a scenario where the factions are (before the scenario), relatively static or stalemated. Also, if you are using PSOM to simulate the effects of a particular set of actions by peacekeeping forces (and reactions by other factions), you only need to run the scenario for about 30 turns, not 50 or 100. A particularly conservative modeler might use turn 32 or 33 given the slight variation in turns 31 and 32. Of course, depending on the scenario, 30 turns could be 30 days or 30 months, and in the latter situation, it might not be realistic to assume that no other external events influence the populations' stances.

If these issues are taken into consideration, PSOM provides a reasonable option for simulating peacekeeping operations and should be the first stop for a military planner or trainer looking at future work in peacekeeping. With the instability in North Africa and the Middle East, this is a valuable tool.

The research in this thesis explored a small number of scenarios in the contested Abyei region at the border of Sudan and South Sudan, with an eye toward providing general guidance to scenario builders. Further research could delve more deeply into the Abyei region model. For example, one possible future research topic would be looking into exactly which input points drove the output values in the parallel plot. Was it primarily the U.S. force protection and ROE that led to the consent values shown, or was it the settings of the tribal forces? Originally, 103 variables were identified to analyze, but only 10 were chosen due to the computational cost; selecting other variables and seeing how they affect the result would be a good future thesis topic. Also, this thesis only looked at all forces using the same strategy (with the exception of one that had half of the

forces attempting genocide, while the other used conventional warfare tactics). A simulation of different strategies, especially the U.S. options, would give information that would be very useful to U.S. planners. Also, while this thesis looked at how consent changed over time, this was done with a static strategy, seeing how consent changes if the strategy changed during turn 5, for instance, would be a useful expansion. Finally, PSOM could be compared with other peacekeeping models; it may be valuable to modify the approaches used in this thesis to assess the different platforms' strengths and weaknesses, and evaluate their suitability for training or planning purposes.

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APPENDIX A. MAIN MODEL NOAB DESIGN TABLE

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
1	5	5	3	3	3	3	4	4	4	4
2	3	2	1	2	2	2	5	2	2	2
3	2	3	5	1	5	5	5	2	3	1
4	1	3	5	2	2	1	3	5	1	1
5	2	1	1	3	2	3	1	5	1	1
6	2	2	1	2	2	2	1	2	3	2
7	1	5	1	2	3	2	1	2	1	1
8	1	3	5	2	1	1	1	1	5	2
9	5	1	1	1	4	1	3	1	2	1
10	4	5	3	4	1	2	1	3	1	2
11	4	4	1	1	1	4	2	1	4	1
12	1	1	1	4	1	3	3	5	1	1
13	1	2	5	5	2	2	2	2	3	2
14	3	1	5	5	1	5	2	5	1	4
15	1	3	2	5	5	1	1	4	5	3
16	1	2	1	5	2	5	1	5	2	5
17	2	2	2	4	3	5	2	1	5	2
18	2	4	1	4	1	3	5	1	5	5
19	5	2	1	5	4	5	2	5	1	3
20	4	5	5	5	2	1	4	5	2	3
21	5	3	1	2	3	5	3	3	4	4
22	3	4	1	1	4	3	3	1	3	4
23	1	2	4	1	3	2	2	5	5	4
24	3	1	2	3	4	3	4	4	5	5
25	4	4	4	1	1	2	1	4	2	4
26	2	5	5	4	1	2	3	3	5	3
27	5	1	2	5	5	5	4	2	4	2
28	2	1	3	4	2	3	4	1	5	5
29	3	1	1	1	2	2	1	4	1	2
30	5	5	4	1	3	3	4	1	5	2
31	1	5	3	1	5	2	4	5	5	1
32	3	5	2	1	3	3	3	2	2	3
33	1	5	5	2	2	1	5	2	5	2
34	3	3	2	2	5	2	4	2	4	3
35	4	5	1	1	1	4	5	2	2	1
36	4	5	1	5	4	3	3	5	2	1
37	4	1	4	4	2	2	3	1	2	5
38	1	5	4	4	2	3	4	4	1	2
39	3	1	4	5	1	2	4	3	5	2
40	5	4	1	2	3	4	5	5	3	3
41	4	2	2	5	2	5	2	5	5	2
42	4	1	5	3	4	3	5	2	1	3
43	2	3	1	5	1	3	2	4	4	5
44	5	5	5	3	2	1	3	1	5	2

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
45	2	4	3	4	1	3	1	5	4	1
46	4	2	2	5	4	1	1	5	5	3
47	3	2	5	2	4	3	3	2	1	5
48	1	3	2	4	3	4	2	1	3	1
49	5	4	2	1	1	3	3	5	5	2
50	4	1	5	2	5	5	3	4	1	5
51	2	1	1	4	4	1	5	1	5	5
52	2	2	5	2	1	2	1	5	2	5
53	1	3	5	5	5	3	2	5	1	4
54	5	2	4	1	4	3	1	1	2	1
55	5	2	1	4	2	1	3	1	2	2
56	5	1	2	1	1	4	3	1	1	1
57	1	3	4	5	4	5	5	5	2	4
58	4	1	1	4	5	3	2	3	2	3
59	3	2	5	2	5	1	4	2	2	3
60	2	5	3	1	3	1	1	4	2	3
61	5	2	2	4	3	1	5	4	1	1
62	3	4	2	1	1	5	3	4	2	5
63	1	1	3	4	1	3	2	1	5	4
64	3	1	5	1	2	4	4	3	5	1
65	4	3	4	5	2	1	5	3	4	2
66	2	1	3	3	5	1	5	1	1	3
67	2	4	3	5	1	3	3	5	2	1
68	4	4	1	1	2	1	1	1	2	1
69	1	2	1	2	1	4	3	4	4	5
70	2	3	3	1	2	2	2	1	5	2
71	1	1	5	2	5	1	2	2	5	5
72	5	1	5	2	2	5	4	4	4	5
73	2	1	1	2	4	1	5	1	3	3
74	5	4	3	5	3	3	1	1	1	4
75	1	3	1	1	5	4	1	3	3	1
76	1	5	3	5	4	2	1	4	5	1
77	1	2	4	1	1	1	4	5	3	1
78	5	5	2	2	2	1	5	3	1	3
79	1	3	1	1	5	3	3	5	2	5
80	2	5	5	1	4	5	2	4	1	1
81	4	3	5	1	3	5	2	2	4	1
82	4	2	4	1	5	2	5	3	4	3
83	2	4	4	1	1	1	1	2	5	2
84	1	4	3	4	1	5	1	4	1	3
85	3	2	5	1	1	2	2	2	3	4
86	2	3	2	5	2	4	4	4	4	1
87	2	4	5	1	1	3	1	1	2	5
88	2	2	1	1	2	3	5	5	1	3
89	4	5	3	4	4	2	2	5	3	1
90	1	4	1	3	3	4	1	2	3	4
91	5	3	1	2	4	1	2	5	3	1
92	1	3	3	3	1	1	2	3	1	2

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
93	2	4	4	4	2	1	2	5	1	3
94	4	1	3	2	5	4	1	3	1	4
95	4	1	3	4	5	1	1	2	2	4
96	2	1	3	2	4	3	5	3	3	1
97	3	5	2	5	5	2	1	1	5	4
98	5	3	1	4	5	3	4	3	5	1
99	2	5	4	3	2	4	2	5	4	4
100	2	5	2	4	5	3	5	1	1	5
101	1	4	1	2	5	4	3	4	4	5
102	2	4	1	4	3	5	4	5	4	1
103	4	4	5	1	1	3	5	5	2	2
104	5	5	3	2	3	3	1	5	4	4
105	4	5	1	5	4	4	4	5	4	1
106	3	4	2	4	2	3	2	2	5	5
107	1	4	5	4	1	2	2	2	5	3
108	4	1	1	4	5	4	2	1	2	5
109	1	4	5	4	3	4	1	3	2	2
110	5	5	3	5	3	4	2	4	2	5
111	2	2	3	2	1	3	2	4	5	4
112	4	5	5	2	1	2	2	4	3	5
113	5	2	3	5	4	4	1	2	5	4
114	1	3	2	4	5	4	3	4	2	1
115	5	5	1	1	1	4	5	2	2	5
116	2	3	5	4	2	1	4	1	3	3
117	3	1	3	4	5	1	2	2	3	1
118	4	3	5	2	3	4	4	3	2	3
119	4	4	4	2	4	2	5	4	2	3
120	3	1	2	4	2	5	5	1	4	1
121	2	5	5	4	1	3	3	4	5	5
122	1	3	1	2	3	1	5	1	3	2
123	5	3	2	2	5	3	5	3	5	3
124	4	5	4	1	2	4	2	1	3	3
125	3	1	4	5	3	3	5	2	2	2
126	1	5	4	5	4	4	3	2	2	1
127	1	2	1	3	2	2	4	4	3	4
128	4	4	2	1	3	5	1	4	2	1
129	1	1	2	1	2	1	3	1	4	2
130	5	5	4	2	4	1	2	3	5	5
131	1	5	5	2	5	2	1	5	4	3
132	3	3	3	2	3	3	1	2	3	3
133	4	1	5	3	5	1	2	5	2	1
134	1	4	3	4	3	5	4	3	3	1
135	3	5	3	2	4	2	3	3	4	5
136	1	1	2	1	1	3	3	5	4	3
137	3	2	1	4	1	2	1	5	3	2
138	3	1	1	2	5	3	5	1	1	2
139	3	2	2	2	2	3	2	2	5	3
140	1	2	4	1	5	5	3	2	5	1

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
141	1	3	1	1	4	4	5	4	3	1
142	5	4	2	5	1	3	4	2	4	4
143	1	2	4	3	2	1	3	2	1	4
144	2	1	1	1	2	5	1	3	4	5
145	1	5	1	3	2	1	4	2	5	4
146	5	1	4	3	5	3	4	1	5	5
147	4	1	4	5	2	2	1	5	2	4
148	2	1	3	4	1	1	2	3	4	3
149	5	4	5	1	2	2	1	2	5	5
150	4	4	1	2	1	2	4	1	4	4
151	4	5	1	5	2	3	4	3	1	3
152	3	2	3	1	2	1	5	1	1	1
153	5	3	3	2	5	3	2	1	4	1
154	3	3	2	5	3	2	2	2	4	1
155	3	5	5	2	4	3	5	3	3	1
156	4	5	2	5	2	3	5	5	5	3
157	1	2	5	5	1	1	4	3	1	2
158	5	4	4	2	2	5	2	5	5	1
159	5	3	3	1	5	1	1	3	1	5
160	4	2	4	5	2	3	3	2	3	1
161	1	4	5	2	5	3	2	2	5	2
162	4	1	2	4	4	2	3	5	3	1
163	2	3	2	2	2	2	4	4	5	4
164	1	4	1	2	3	3	3	5	1	3
165	4	1	2	3	1	2	2	3	2	3
166	1	5	2	4	3	4	1	4	5	2
167	3	1	2	4	4	1	3	1	3	3
168	2	1	5	3	4	3	2	1	5	5
169	1	1	3	1	3	2	3	3	5	3
170	1	2	1	4	5	1	5	5	2	4
171	1	1	3	3	2	1	5	4	5	2
172	2	2	3	3	4	2	5	5	4	3
173	4	4	1	4	2	1	5	5	3	5
174	5	1	2	5	5	2	5	4	2	5
175	5	4	3	4	1	5	3	1	1	5
176	3	2	2	4	3	4	2	3	4	2
177	4	4	2	3	5	1	3	3	5	5
178	5	4	2	2	3	2	2	3	4	2
179	4	5	1	1	2	4	2	3	3	3
180	2	5	5	4	2	3	1	4	2	4
181	4	2	1	2	5	3	2	4	1	1
182	2	1	1	2	2	1	4	5	3	5
183	5	1	2	3	1	5	5	4	3	3
184	1	4	2	1	4	3	5	3	5	5
185	1	3	1	4	5	2	2	4	1	5
186	5	1	4	1	2	2	2	3	2	1
187	3	4	2	2	5	2	2	5	1	1
188	2	5	1	2	1	4	5	5	3	3

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
189	3	3	3	5	5	5	2	4	1	5
190	3	3	5	1	5	5	2	2	4	4
191	1	3	1	3	4	1	4	2	3	5
192	1	2	3	5	1	3	4	3	1	4
193	2	4	3	5	1	1	5	3	5	4
194	2	1	5	5	4	4	2	4	4	2
195	3	1	1	3	5	2	4	4	2	5
196	3	3	3	5	3	4	5	1	5	5
197	4	5	4	3	4	5	3	5	3	3
198	2	3	2	1	5	1	4	5	4	4
199	2	5	2	2	4	1	4	2	1	4
200	1	4	2	3	1	4	4	4	5	4
201	1	1	1	1	3	3	1	1	2	5
202	3	2	5	2	4	2	2	2	4	5
203	5	5	4	2	2	2	5	5	4	2
204	5	3	5	4	2	2	3	2	2	3
205	2	1	1	2	1	4	1	4	1	5
206	2	3	3	5	2	2	2	4	3	1
207	4	1	4	1	3	1	1	3	1	4
208	4	2	1	4	1	2	2	3	2	4
209	3	4	5	5	1	1	5	1	4	1
210	4	2	3	3	2	2	1	2	3	2
211	2	5	1	5	1	1	4	2	3	4
212	5	1	3	2	3	2	5	4	4	5
213	2	5	4	1	4	1	1	5	4	5
214	1	3	1	2	5	1	1	1	4	1
215	5	4	2	2	2	3	3	5	3	3
216	3	4	5	5	4	4	5	4	2	5
217	5	3	5	1	3	1	1	5	5	4
218	5	2	4	3	3	1	4	2	1	4
219	2	4	4	4	2	4	5	1	1	1
220	3	1	4	2	2	5	5	5	5	3
221	5	5	5	3	4	5	2	2	1	5
222	5	5	3	3	1	2	2	3	4	3
223	2	1	3	1	1	5	4	2	5	2
224	3	4	5	5	4	1	5	2	1	2
225	1	1	4	4	3	5	5	1	3	1
226	5	3	5	1	2	4	5	2	3	3
227	1	3	4	2	2	1	1	4	3	5
228	4	4	5	1	2	2	1	5	5	5
229	5	5	2	4	1	4	3	3	1	5
230	2	1	5	3	4	3	2	2	4	5
231	1	5	4	5	5	1	3	2	1	2
232	5	2	3	1	2	1	3	2	4	1
233	4	4	2	5	5	5	2	3	1	2
234	2	2	2	4	1	3	1	4	1	4
235	3	1	1	4	1	4	1	3	2	4
236	3	4	3	3	3	3	1	5	5	5

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
237	4	2	4	5	3	1	1	4	4	1
238	5	4	1	1	1	5	4	3	3	2
239	5	2	2	2	3	5	4	4	5	4
240	3	4	1	2	1	2	4	4	3	5
241	5	2	4	5	2	2	3	4	2	1
242	3	1	3	1	4	4	3	3	1	1
243	4	4	2	2	1	1	4	5	2	4
244	2	1	4	2	5	4	2	5	4	4
245	1	1	4	1	1	5	4	4	3	5
246	5	1	5	4	2	2	1	3	4	2
247	5	3	4	1	4	2	5	3	1	5
248	3	5	4	5	5	3	5	4	2	1
249	2	1	2	4	2	4	5	4	1	2
250	5	4	5	2	3	3	2	1	2	1
251	2	1	2	1	2	4	4	1	2	4
252	2	1	2	1	4	5	1	4	5	4
253	4	1	5	5	4	2	4	1	3	2
254	4	1	5	5	1	3	4	1	2	3
255	3	1	1	2	5	3	4	1	5	5
256	4	1	3	3	2	4	2	3	5	4
257	1	1	2	1	1	4	2	2	1	2
258	2	2	2	5	3	2	1	5	5	3
259	2	1	1	4	5	4	3	2	5	4
260	2	3	4	2	3	4	5	4	2	5
261	3	4	4	3	5	5	1	5	2	5
262	4	1	3	1	4	5	1	1	5	1
263	5	4	1	2	5	1	5	4	4	2
264	4	2	4	5	1	4	5	1	3	5
265	4	4	2	5	3	1	1	4	5	1
266	3	5	2	1	5	1	1	4	3	2
267	2	4	4	1	2	5	5	5	3	3
268	1	1	4	2	1	2	3	5	4	4
269	4	2	2	5	5	1	3	4	1	3
270	2	3	2	3	4	2	3	3	3	1
271	5	2	4	5	2	4	4	2	2	1
272	3	2	4	2	3	1	2	4	1	1
273	2	1	5	1	1	4	3	2	1	5
274	5	2	1	4	3	5	1	3	3	2
275	5	3	2	4	4	5	1	1	5	3
276	4	1	1	1	1	2	2	3	4	2
277	1	4	4	1	1	1	3	3	1	2
278	3	1	4	3	1	5	2	3	2	2
279	2	5	4	2	1	2	4	1	3	2
280	4	2	5	4	3	1	4	5	4	5
281	1	2	2	5	2	5	1	1	2	5
282	1	5	1	1	4	3	1	3	3	1
283	2	4	4	5	5	4	4	1	2	2
284	2	4	1	3	5	4	2	4	2	3

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
285	2	5	3	3	5	5	1	2	2	5
286	3	3	5	3	5	3	1	2	2	2
287	2	4	3	5	5	4	4	2	3	2
288	4	4	4	3	5	2	2	1	5	5
289	3	5	3	3	5	2	3	2	5	1
290	4	2	3	5	1	5	2	3	1	1
291	1	4	5	3	1	5	5	3	1	5
292	1	3	4	2	2	1	4	5	3	3
293	2	3	4	5	5	2	2	3	3	1
294	3	5	1	1	1	1	3	2	2	2
295	4	5	1	4	3	5	5	4	2	4
296	5	5	4	5	1	4	3	3	4	5
297	4	5	1	1	5	5	5	5	5	5
298	5	2	5	5	4	3	4	4	1	1
299	2	5	1	2	3	1	4	3	1	4
300	4	5	2	5	3	3	5	1	1	5
301	5	4	4	1	4	2	5	4	3	2
302	5	4	1	5	1	3	1	3	3	1
303	1	3	5	3	3	5	1	3	3	1
304	5	4	1	4	2	4	3	3	1	5
305	3	2	3	3	1	2	4	1	4	1
306	2	2	4	5	4	1	3	1	4	1
307	5	5	5	4	4	2	3	1	3	5
308	4	5	5	2	5	2	5	1	3	2
309	1	4	3	1	4	4	4	1	2	1
310	1	2	5	5	3	2	4	1	5	1
311	2	3	3	2	5	4	3	4	2	1
312	5	1	3	3	1	5	5	4	4	4
313	5	3	1	2	4	5	3	5	5	5
314	5	5	5	3	2	2	1	1	2	3
315	4	2	5	2	1	3	5	5	1	4
316	2	2	2	5	1	2	5	2	3	5
317	5	1	5	1	1	2	4	3	1	4
318	5	3	3	5	1	1	4	3	5	5
319	5	5	5	4	3	5	1	1	3	3
320	1	5	1	1	5	3	4	1	4	5
321	1	1	4	2	1	2	2	3	1	5
322	2	3	2	1	4	4	3	2	2	5
323	5	2	4	1	3	1	5	2	1	4
324	1	5	5	3	1	2	3	3	1	4
325	2	5	1	4	1	5	1	2	4	5
326	1	3	2	5	2	1	2	2	4	4
327	4	1	2	4	2	2	5	2	1	3
328	1	2	5	4	1	2	1	4	5	2
329	3	5	1	5	3	5	4	2	4	2
330	5	4	5	5	4	5	1	5	3	3
331	4	2	5	3	3	1	1	4	3	2
332	5	4	4	3	1	5	2	1	2	4

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
333	3	5	4	4	4	4	4	4	5	2
334	2	4	1	3	5	5	1	2	2	1
335	5	4	3	4	1	4	2	1	1	5
336	2	2	3	3	5	1	1	1	1	4
337	1	2	5	3	4	1	3	2	5	2
338	3	1	2	3	1	5	2	1	5	2
339	1	3	5	4	2	4	4	4	1	2
340	5	4	5	3	2	4	4	5	5	3
341	1	5	2	4	2	5	1	3	1	4
342	3	5	2	3	5	3	3	5	5	4
343	1	5	4	5	2	2	3	1	4	2
344	5	2	3	1	2	2	5	2	3	2
345	5	4	5	3	4	2	1	1	5	3
346	5	2	3	1	1	3	2	3	5	2
347	5	3	2	4	2	5	2	1	1	1
348	2	2	5	3	4	3	3	4	5	1
349	2	2	5	2	1	1	3	3	3	1
350	1	5	5	3	4	5	5	5	4	4
351	5	3	1	2	3	1	2	3	3	2
352	1	1	4	1	5	5	5	3	3	1
353	4	3	2	5	2	4	4	5	3	4
354	4	2	1	4	4	1	2	5	3	3
355	4	5	3	4	4	3	2	5	1	3
356	4	4	4	3	5	4	4	1	5	4
357	2	1	2	5	3	3	5	5	4	3
358	3	1	1	4	2	2	1	1	2	1
359	5	2	5	5	5	4	3	2	4	2
360	5	1	2	4	3	5	5	1	2	4
361	1	5	1	2	2	4	3	1	1	2
362	5	3	4	3	1	5	3	1	4	3
363	4	3	5	5	3	4	3	5	1	1
364	1	3	3	3	5	4	1	2	5	3
365	1	3	1	1	4	5	2	4	3	2
366	2	2	5	1	2	3	2	4	4	5
367	5	2	1	4	3	1	4	3	4	4
368	1	2	2	5	1	2	4	1	1	3
369	3	3	1	5	5	4	4	4	1	5
370	3	5	5	2	3	1	2	5	5	3
371	3	2	3	3	4	5	1	2	2	4
372	5	1	2	2	1	1	1	5	3	2
373	2	4	4	3	2	1	2	2	2	2
374	5	2	4	5	4	1	1	3	4	3
375	2	2	1	4	2	2	4	5	2	1
376	5	1	1	5	1	1	3	3	4	1
377	1	2	3	3	3	2	1	4	3	5
378	4	3	1	1	2	2	1	2	4	2
379	4	4	4	5	4	4	1	4	5	1
380	1	2	2	3	5	1	4	3	1	5

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
381	2	3	1	3	1	3	2	1	2	4
382	2	5	2	3	3	4	1	1	4	5
383	3	1	4	3	1	2	4	5	4	3
384	3	2	2	5	1	1	3	3	2	2
385	3	2	3	3	5	1	2	2	3	2
386	4	5	4	5	5	4	3	5	1	5
387	1	4	1	4	3	3	4	3	5	3
388	4	5	2	2	2	1	2	2	1	3
389	5	3	4	5	4	4	5	2	1	2
390	1	4	4	4	5	2	2	5	5	2
391	2	3	2	2	2	5	2	5	1	2
392	4	5	3	3	5	2	5	1	3	1
393	3	1	5	3	5	3	2	4	2	4
394	1	3	5	5	4	4	1	3	1	5
395	4	2	1	5	1	1	3	4	5	5
396	2	5	2	1	4	2	3	3	1	4
397	1	4	3	3	1	2	4	3	3	4
398	3	3	2	2	4	4	1	1	4	4
399	4	2	5	2	5	1	3	4	1	3
400	4	3	3	5	5	1	1	1	4	5
401	3	2	2	3	5	1	3	1	2	3
402	5	4	4	3	1	5	4	3	5	3
403	5	3	1	1	4	3	2	2	2	3
404	3	3	3	5	2	2	5	5	3	4
405	2	1	2	3	5	1	4	4	5	4
406	3	2	4	5	2	1	2	5	2	5
407	5	5	2	3	2	5	1	2	4	2
408	4	1	4	2	2	3	4	4	5	1
409	2	2	3	2	5	1	5	1	1	2
410	5	4	1	2	3	2	2	5	2	5
411	5	1	1	4	5	3	4	5	1	2
412	1	2	3	5	3	2	5	5	3	3
413	1	2	4	2	4	3	3	5	4	3
414	2	3	2	1	3	4	5	2	3	4
415	1	4	5	4	2	5	5	4	4	3
416	3	5	1	4	2	3	5	5	4	1
417	3	1	5	2	1	3	3	2	3	2
418	2	5	5	1	4	2	3	5	2	3
419	4	2	1	5	5	3	5	3	2	4
420	4	1	3	2	4	4	2	5	5	1
421	1	5	3	5	3	5	2	3	3	4
422	4	2	2	1	3	3	4	2	1	1
423	3	2	5	2	4	1	3	5	2	3
424	1	1	3	5	5	5	5	3	3	5
425	4	2	3	4	5	2	5	3	4	4
426	1	1	3	3	1	4	2	1	2	4
427	3	2	5	1	4	5	1	4	2	4
428	1	4	1	5	1	4	3	1	5	2

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
429	5	3	3	1	5	4	5	5	3	2
430	4	2	1	5	3	5	4	2	5	2
431	5	3	2	2	3	4	3	5	4	1
432	2	3	3	4	2	4	3	2	5	2
433	5	1	3	1	2	5	2	5	1	2
434	2	1	2	3	2	5	2	1	3	4
435	2	1	5	5	1	4	1	3	1	4
436	3	5	1	3	5	2	3	3	3	5
437	3	5	5	3	2	3	1	1	5	4
438	5	1	3	1	2	3	1	2	2	3
439	1	4	1	4	1	2	3	5	5	5
440	1	2	3	5	4	4	4	1	3	4
441	1	5	5	5	5	5	1	3	1	2
442	3	4	4	3	3	4	5	5	3	1
443	3	5	2	1	3	5	4	2	1	1
444	1	1	1	3	2	5	1	4	5	2
445	1	5	4	3	3	2	5	1	2	2
446	5	2	1	3	2	1	2	5	4	3
447	1	4	2	5	5	4	2	2	2	3
448	5	5	4	2	3	5	5	5	3	3
449	4	3	4	1	4	4	5	1	5	3
450	3	2	3	1	1	3	2	4	4	1
451	5	3	3	4	3	1	1	2	1	5
452	3	3	2	4	5	2	2	4	2	1
453	2	1	2	1	3	2	4	4	2	1
454	2	3	2	2	5	4	2	4	5	1
455	3	3	5	1	2	5	4	4	2	1
456	1	3	4	1	4	1	1	1	1	5
457	3	2	1	4	5	4	1	2	4	1
458	2	4	3	2	5	1	3	5	5	1
459	5	2	4	5	3	4	3	4	2	2
460	1	1	1	5	1	3	1	4	4	3
461	2	3	2	1	3	2	1	2	1	4
462	2	5	2	3	3	5	4	4	3	1
463	5	4	4	1	1	3	1	1	4	5
464	1	2	4	4	1	5	5	2	4	1
465	4	4	5	3	2	2	4	5	1	5
466	3	5	5	3	3	5	5	1	1	1
467	2	1	3	3	2	2	4	1	4	4
468	5	2	4	5	4	2	2	1	1	3
469	5	5	1	4	4	2	5	3	4	4
470	5	1	2	5	5	5	3	3	4	5
471	3	1	5	4	3	3	4	4	4	1
472	5	4	1	3	3	1	1	1	2	1
473	3	2	3	3	4	1	3	4	1	2
474	4	5	3	2	1	3	3	1	4	2
475	2	3	3	3	1	1	2	1	1	4
476	3	1	2	2	2	4	5	5	3	3

Table 8. NOAB design for main model

DP	UN_ROE	UN_FP	Rizeigat ROE	Rizeigat FP	Messiria ROE	Messiria FP	Fur_ROE	Fur_FP	Arab_ROE	Arab_FP
477	2	3	3	2	2	5	5	5	1	5
478	3	2	1	5	1	5	3	4	2	1
479	5	2	4	2	5	4	5	1	3	4
480	5	5	2	4	3	1	1	2	2	2
481	4	3	1	5	5	2	3	5	4	2
482	3	3	2	1	3	3	5	2	1	2
483	1	2	2	1	3	4	1	1	3	2
484	3	5	2	3	2	2	5	1	4	5
485	2	1	4	4	4	5	5	4	5	5
486	1	2	1	4	4	1	4	4	3	4
487	1	5	1	1	3	2	5	5	2	2
488	4	1	5	3	2	5	1	4	2	3
489	5	3	3	1	3	3	1	3	2	2
490	5	4	2	4	3	1	1	5	1	1
491	3	1	5	5	4	1	2	3	3	4
492	1	5	3	4	1	1	5	1	4	1
493	2	2	1	3	2	5	3	4	2	2
494	4	5	2	5	3	1	2	1	5	5
495	5	4	3	3	3	2	1	2	3	3
496	3	1	4	1	5	4	1	4	1	3
497	5	3	3	2	3	3	2	1	5	5
498	1	3	2	2	4	1	2	3	5	2
499	1	2	5	4	5	2	2	2	2	4
500	3	4	5	2	1	1	5	2	1	5
501	1	4	5	4	4	5	5	3	5	2
502	1	5	4	3	2	4	2	1	3	2
503	3	5	2	3	4	2	2	5	3	4
504	5	1	2	3	5	2	2	5	5	5
505	2	2	5	5	4	4	1	3	2	4
506	5	2	4	3	2	5	4	3	4	3
507	4	1	3	1	5	3	5	2	5	3
508	5	2	2	4	1	5	1	1	3	1
509	3	3	2	5	2	3	1	3	5	1
510	1	4	3	4	4	5	5	1	5	3
511	3	2	2	4	1	3	1	4	4	1
512	4	1	3	1	4	2	4	4	2	3
513	3	3	5	1	1	2	5	5	5	2

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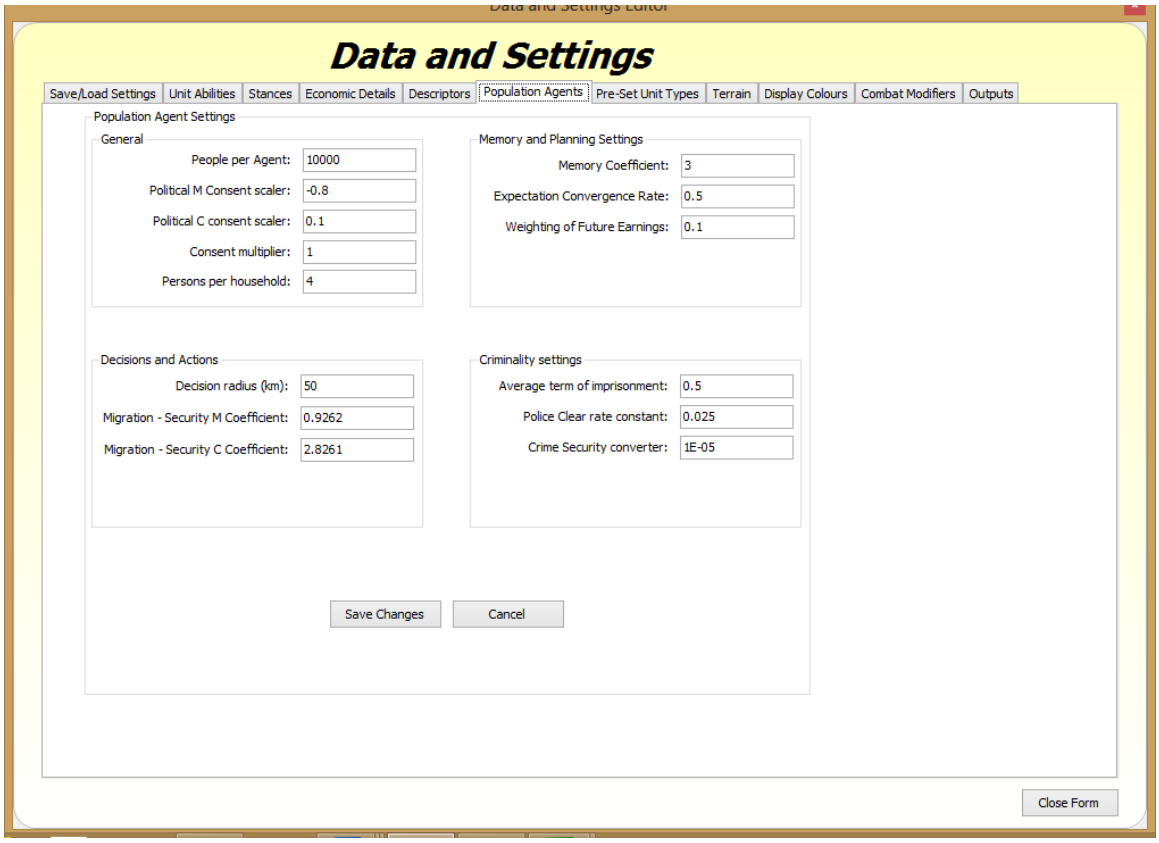
APPENDIX B. CREATING / EDITING SCENARIOS IN PSOM

A. SETTINGS FILE

First, even when creating a new scenario from scratch, an existing settings file will be edited. Most of the settings will not need to be changed anyway, but a few key items should be looked at.

Figure 16. Data and settings, population agents



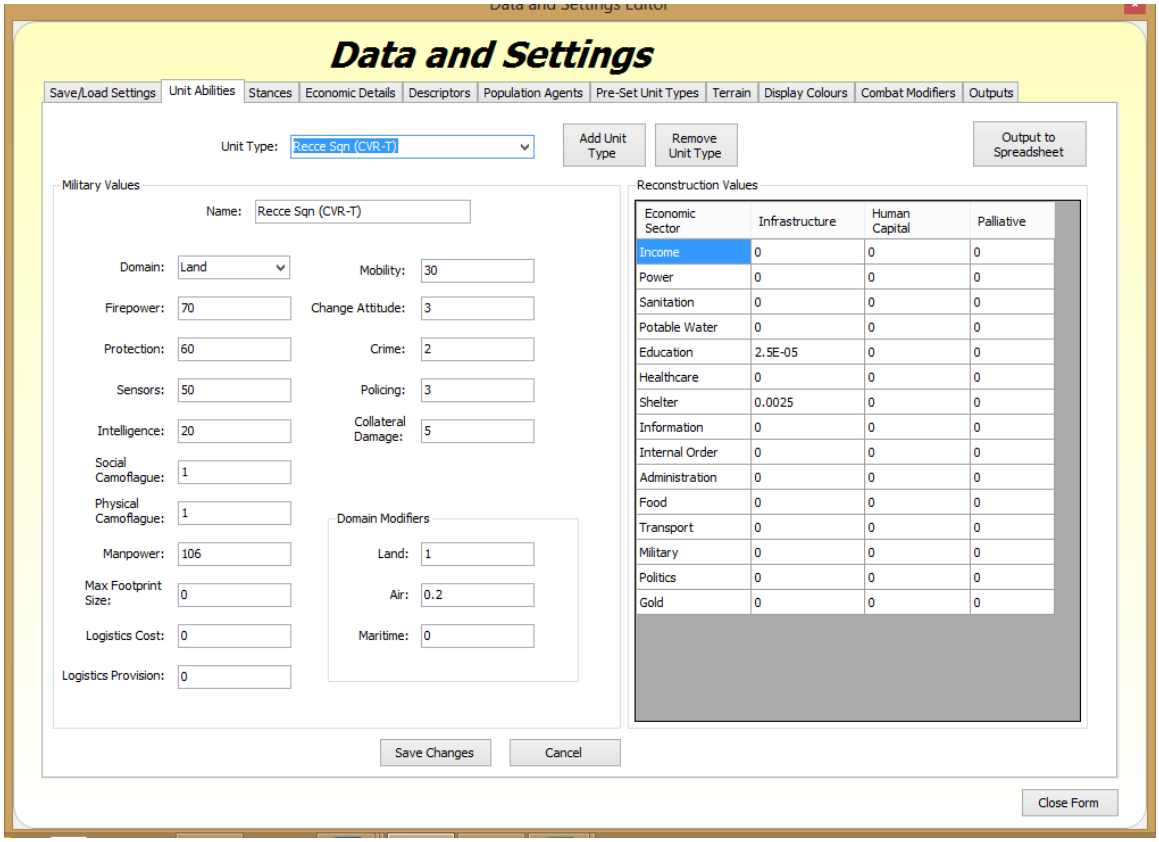
Under **Population Agents**, the *People per Agent* sets how large a group a single population agent represents. If you have a billion people, then a population agent size of one million might be better. If you were modeling a small area with only 100,000 people, a population agent size of 100 would work. As a rule of thumb, about 1000 agents is a good number to work with. Too few and you will be unable to have one population

outnumbering another in an area or be able to show population in sparsely populated areas. Too many and you will multiply your workload. The Sudan Scenario, modeling about 10 million people, had 1160 population agents of 10,000 people each. Even so, some desert areas with below 1000 population were considered "empty" for the simulation.

Also under **Population Agents**, the *Decision radius* shows how large each map square will be. While each subsection of the map needs to be a square of this length on each side, the map itself can be a rectangle as long as it is made up of these squares. A map with one region would be nearly pointless, while a map with 10,000 regions would have a huge administrative cost for marginal improvement. A map with 100–200 regions seems to work well.

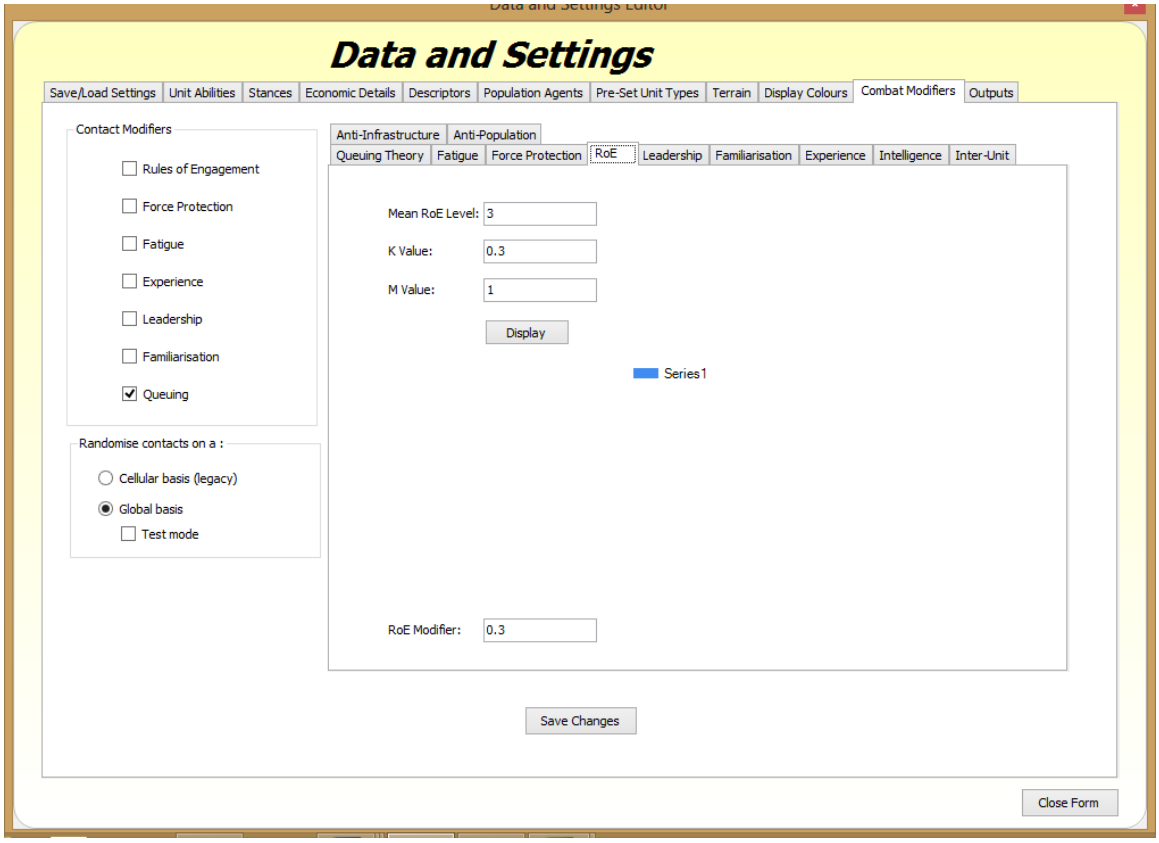
The last item under **Population Agents** to look at is the *Memory Coefficient*, which determines how quickly a population agent (a group of people of a common ethnic group in a single region) will forget a positive or negative action against their ethnic group or an ally that they are aware of.

Figure 17. Data and settings, unit abilities



It can be useful to review, and possibly add to the **Unit Abilities** and possibly the **Pre-Set Unit Types**. Pre-Set Unit Types are categories of troops that can allow you to edit characteristics of the included units as a group.

Figure 18. Data and settings, combat modifiers



An area in the settings file that you need to consider is the **Combat Modifiers**. You should examine all of these numbers, but especially *RoE* and *Force Protection*. The former determines how much force military units will use in combat (collateral damage) which affects population security values, and consent values to a lesser extent. Force Protection determines how aggressive a force is to prevent potential hostiles from approaching; a higher number in this value means higher collateral damage, which will reduce population security.[51] Note that unit ROE and Force Protection can be set to other values in the scenario editor for each unit. This allows a side to use a different value for some or all of their forces, or for different sides to have different combat rules.

[51] Marlin, "Ascertaining Validity in the Abstract Realm," 81–82.

Another important note is that the settings file can be switched out between turns of a scenario. Two possible uses of this would be either to try a scenario with different underlying values, or to change the population's settings in the middle of a training simulation. The latter would allow the population to change their *memory coefficient*, or how long they remember positive and negative actions, in the middle of a scenario, forcing the officers being trained to react to this change.

B. SCENARIO FILE

The next step is the Scenario Editor itself. Some important points to consider are the difference between **Factions** and **Ethnic Groups**. Factions are the directed and active forces; they have military forces and are controlled by a player or trainer. Ethnic groups represent the passive populations; they are the objectives of the simulation. Factions can include both official governments and militia/rebel groups.

Figure 19. Scenario editor, factions

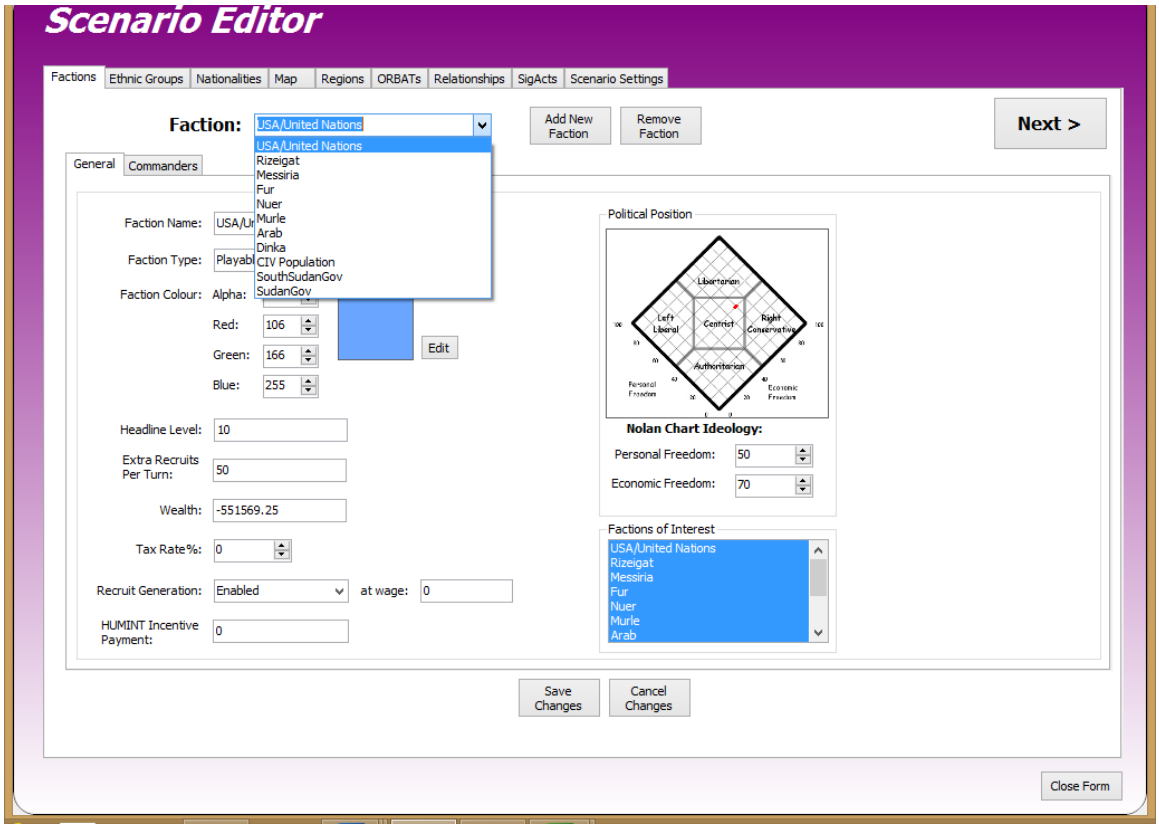
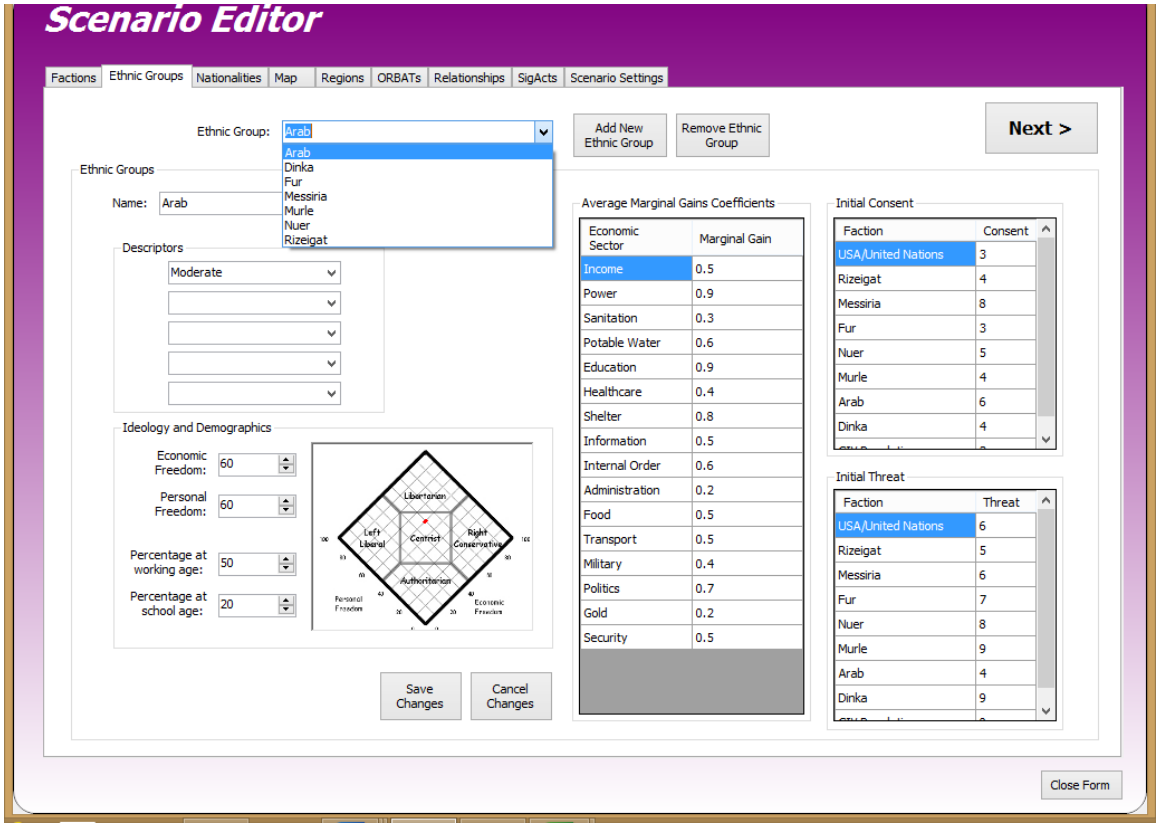
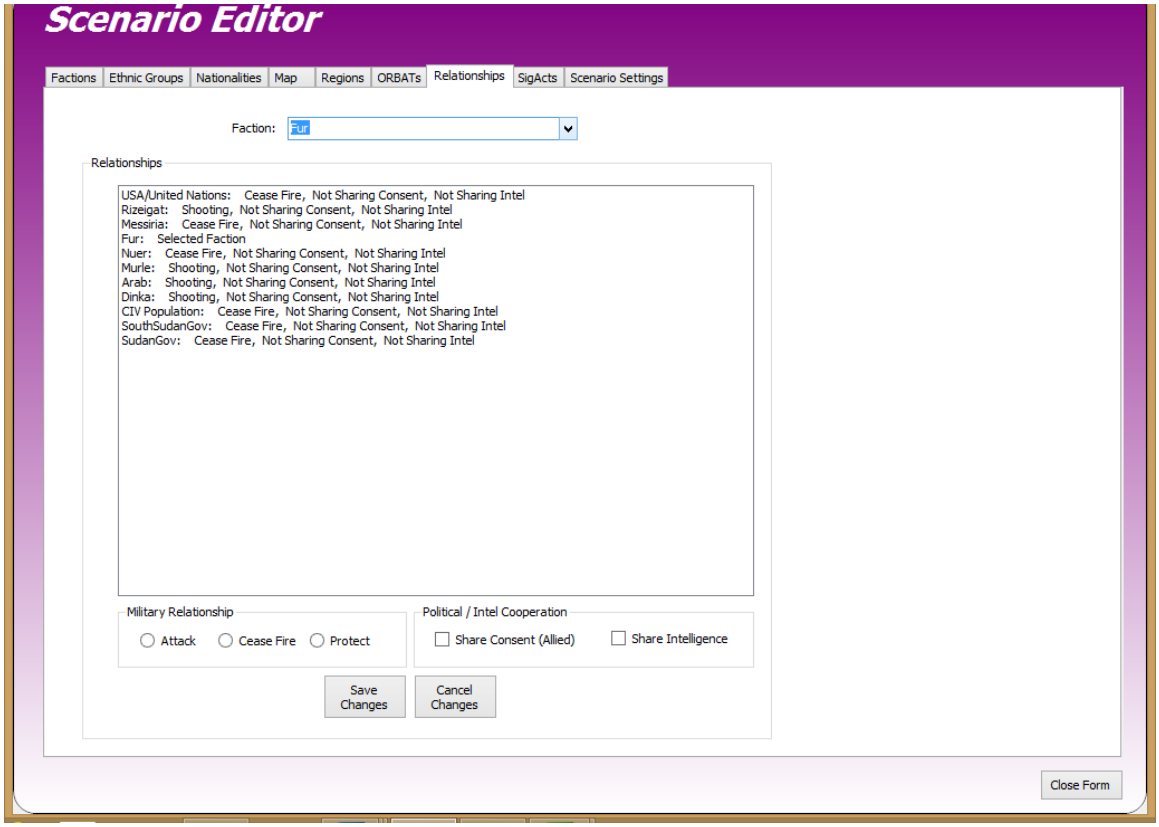


Figure 20. Scenario editor, ethnic groups



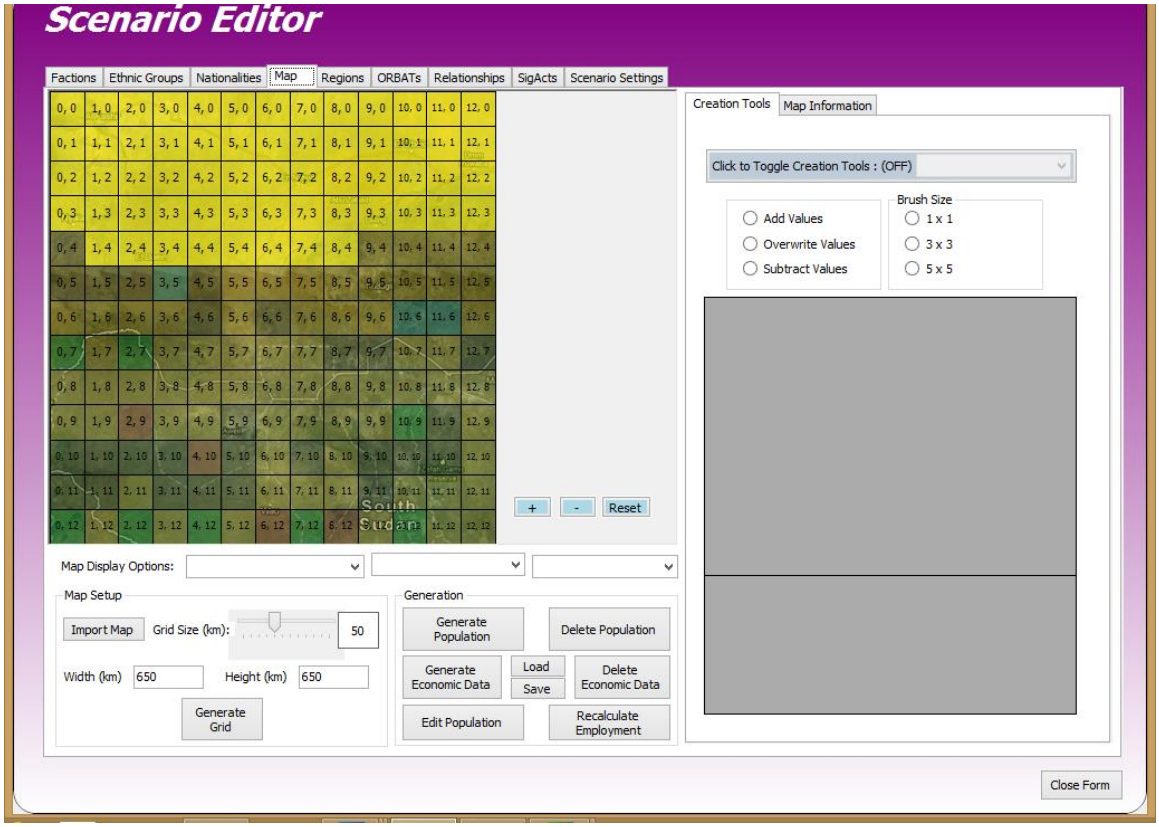
After specifying the factions, you must set the **Relationships**. At first, this just seems to set who is fighting whom, but both the *Share Intelligence* and the *Share Consent* have important effects. Share Intelligence allows sides to share information about where hostile forces are located and what they are doing, but more importantly, the Share Consent allows a faction's positive (or negative) actions to also affect the faction sharing consent. An example of this is if an Ethnic Group faction is seen as supporting the local government, their actions will increase or decrease support for the government.

Figure 21. Scenario editor, relationships



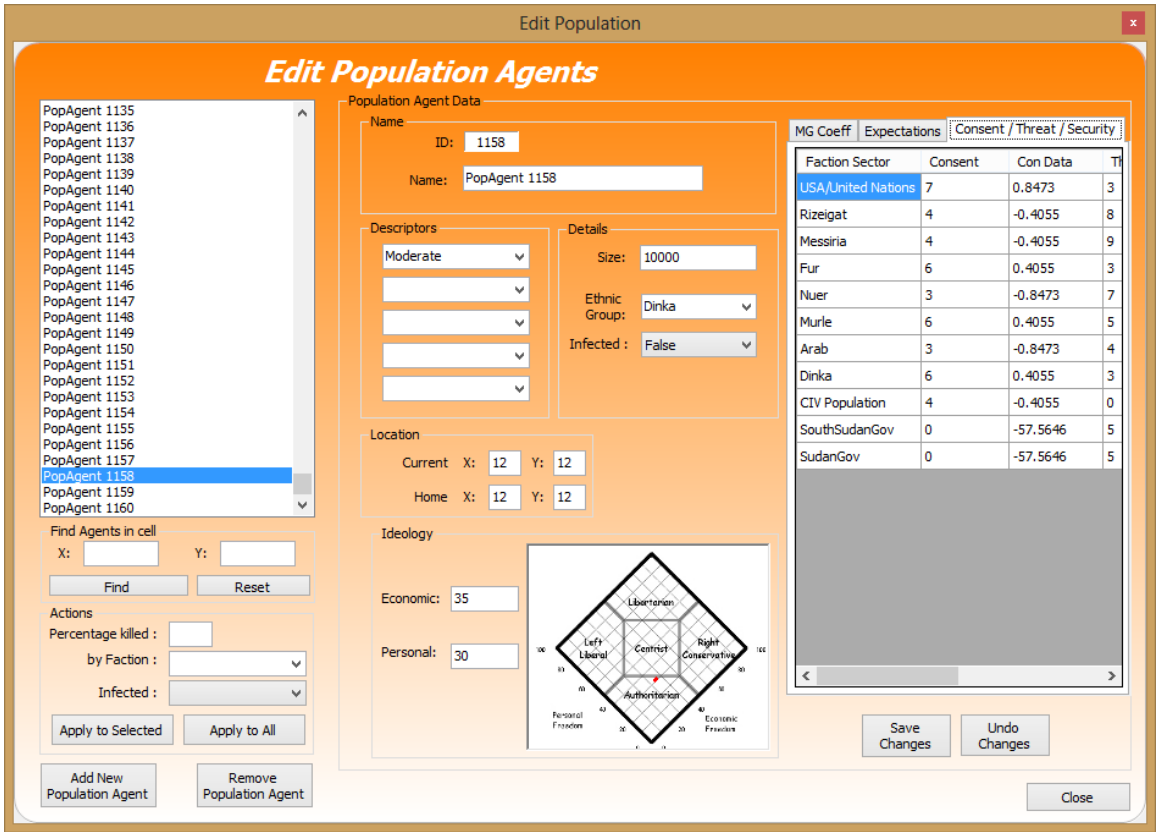
You will need to import your map of the area. As discussed before you will need it to be divisible into squares of the size determined by the settings file. In the **Map** tab set the width and height of the map, then set the terrain types. Then you will need to place the population by number and ethnic group. It is probably easier to set this by XML import, but it can be done via the GUI. The GUI can also be used to verify numbers or modify them. Note that you will want to set the population of an area as multiples of population agents, not as some in-between number (and remember that a population agent can only be one ethnic group).

Figure 22. Scenario editor, map



Once the population is placed, you will need to set the consent and security values. You can manually set them, but this means typing in two numbers for each of your 1000 or so agents. Instead, you can edit the XML files to set large numbers at a time. It is easy enough to set the consent values for all members of an ethnic group to a single value, which means putting in 10 or so numbers, but it is more difficult to edit the security values. Fortunately, the values start at 10. This is probably not the value you want at the start of a simulation that represents a conflict zone. If you do not correct this, then security values will drop in the first turns as security goes from "perfectly safe" to "combat occurring."

Figure 23. Edit population agents



A potential solution is to set up your combat forces while using code manipulation to hold unit and population sizes constant. Then you can run the simulation for a period of time to allow the conflicts to change the security value organically, until it reaches an equilibrium state. Since this was suggested by one of the original programmers of PSOM, this should not have the problem that consent values have with the equilibrium state after several turns promptly changing when put back into a starting state. Of course, if you do not know how to do code manipulation in this way, another method would be to track the changes to the XML file, and then put the final security values into the initial file.

Another important issue in PSOM is the economy. Entering values in every economy section is far too time consuming, copying information from one cell to another in the XML will save you a lot of time. Try to ensure, however, that the property and

construction in each region represents the population in that region (with the possible exception of “abandoned property,” belonging to a group forced out of their homes).

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