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Mao with Smart Phones and Internet? A Comparison of Classic Guerrilla Warfare with Fourth and Fifth Generation Warfare Using an Agent-Based Model for Simulation

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Approval of the Dissertation Committee

This dissertation has been duly read, reviewed, and critiqued by the Committee listed below, which hereby approves the manuscript of Jerry Taylor Sink as fulfilling the scope and quality requirements for meriting the degree of Doctor of Philosophy in Political Science with a concentration in World Politics and Methods.

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Abstract

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Jerry Taylor Sink

Claremont Graduate University: 2020

Fourth Generation Warfare (4GW) theory shares many characteristics of classical guerrilla warfare (CGW) theory in security studies literature. Proponents claim that 4GW is a revolution in war that overturns traditional measures of military power, while critics counter that 4GW is simply CGW in an updated context. Another group posits Fifth Generation Warfare (5GW), which adds additional information-age technologies and uses “any and all means,” (military and extra-military) to attack both the enemy’s will and capability to resist. The irregular subset of 5GW strategies appear to be an extension of 4GW with the addition of advanced information-age technologies: mobile phones and internet spreading propaganda instantly to friendly groups as well as national and trans-national enemies, while unconventional tactics such as suicide bombings and terrorist actions attempt to drain the will of opponents to continue the fight. The CGW and 4/5GW strategies are modeled in an agent-based simulation to evaluate similarities and differences in speed to victory, territory controlled, and the identity of the winning side. Emergent behaviors are compared with historical data.

Fourth Generation Warfare (4GW) as conceptualized by numerous military scholars shares many characteristics of guerrilla tactics in the classical military literature of Sun Tzu, Wellington, Clausewitz, Mao, and Giap. Proponents of 4GW claim that its development has

significantly altered the ratio of strength of industrialized and guerrilla forces, and thus the likelihood of weaker forces (as measured in previous military contexts) prevailing against forces assessed by traditional measures as stronger. Critics point to a lack of intellectual rigor in defining the salient characteristics of 4GW and charge that it is simply a re-statement of classical guerrilla war (CGW) tactics, albeit with improved communications and propaganda capabilities in a social media cultural context.

This research models CGW and 4GW in conjunction with the irregular subset of 5GW in an agent-based simulation using NetLogo software (Wilensky, 1999) in order to explore differences in time and probability of victory and increased area of territory controlled by 4GW and irregular 5GW forces. These forces are then pitted against their respective industrial-age and information-age opponents. Emergent behaviors offer insights into the similarities and differences of CGW. The outputs are then compared to historical data to help answer the question of whether 4/5GW comprise a significant military revolution that threatens to upend traditional measures of military superiority, or they are merely an adaptation of old tactics to a new context.

The results generally favored the rebels in both CGW and 4/5GW scenarios. Increasing Red Communications capability in the 4/5GW scenario overall increased Red Territory controlled as compared to the CGW scenario. However, increasing Blue Communications capability also increased Red Territory gained in both models. This could be interpreted that an overall increase in communications capabilities leads to more aggressive tactics and more engagements for both sides. Blue and Red communications in the 4/5GW scenarios are also associated with a decrease in both Red and Blue time to victory, indicating that the pace of engagements is accelerated in the 4/5GW scenarios. Finally, the model comparing identity of victor after 10 years produced mixed results. An increase in Red Communications was associated with a decrease in the log-odds of Blue Victory after 10 years in 4/5GW model, as expected. However, an increase Blue Communications also appeared to be associated with an increase in the log-odds of *Red* Victory in the 4/5GW model, a somewhat contradictory result. The addition of 21st century technologies seemed to change the overall dynamic compared to CGW only in specific cases, and usually only marginally.

The research project was purposefully designed so that the 4/5GW capabilities would be additions to a basic model of guerrilla warfare. There is danger that these additions were simply insufficient in modeling the true extent of the differences between the two concepts of war, and that 4/5GW tactics are, in fact, revolutionary and not evolutionary. Further study is required to answer the question conclusively.

Acknowledgements

A dissertation by its nature is a group effort, and this one is no exception. I'd like to gratefully acknowledge the staff at Claremont and my advisory committee, who patiently guided me through the program. Eliana Leon, Gwen Smith, and Lauren Copeland put up with my constant requests and provided gentle reminders of due dates.

Professor Zining "Zingy" Yang taught me how to code in NetLogo, and her happy enthusiasm for the project helped me to believe that I could complete it. Evan Travis at the University of Illinois did the lion's share of coding my programming "ideas" to produce a workable model.

Professor Leif Rosenberger, an accomplished economist who has advised three combatant commanders (the highest operational job in the U.S. military) in two different regions of the world, was invaluable in helping me to think about the problem and provided perspectives that I wouldn't have otherwise considered.

I was honored to have Professor Jacek Kugler, who needs no introduction to anyone in the field, on my committee and as an advisor as I was going through the program. Noting my graduate education in engineering, he encouraged me to choose methods as my second subfield. During the dissertation process he quickly zeroed in on crucial issues with my approach and execution and helped get me back on track.

Finally, I need to thank Professor Mark Abdollahian, a brilliant, prolific practitioner and my committee chairman, for his infinite patience and clear guidance as I struggled first to conceptualize a research project and then later as I tried to figure out the next actions at each step. His kind and insightful assistance was truly the key to getting this project to the finish line.

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Chapter 1 – Introduction

Beginning with several U.S. Marine Corps officers writing in military professional journals, arguments emerged in the late 20th and early 21st centuries that military strategies for prosecuting interstate conflict on land had developed into "Fourth Generation Warfare" (Lind et al, 1989). The first three "generations" of battle since the development of firearms were characterized successively by: 1) linear formations to mass musket and cannon fire, 2) entrenchment and heavy firepower to suppress deadly artillery, machine gun, and rifle fire on linear fronts, and finally, 3) formations of planes and tanks to break through enemy defenses and wreak havoc in the enemy's rear areas. According to these authors, Fourth Generation Warfare (4GW) developed as a response by weaker nation-states, insurgencies, and transnational organizations to the superior firepower and technology of industrialized nations.

> *4GW uses all available networks – political, economic, social and military – to convince the enemy's political decision-makers that their strategic goals are either unachievable or too costly for the perceived benefit. It is rooted in the fundamental precept that superior political will, when properly employed, can defeat greater economic and military power. 4GW does not attempt to win by defeating the enemy's military forces. Instead, combining guerrilla tactics or civil disobedience with the soft networks of social, cultural and economic ties, disinformation campaigns and innovative political activity, it directly attacks the enemy's political will. (Hammes, 2005).*

Now, the term 4GW has been adopted by the military as shorthand for the evolution of warfare into a conflict that is not waged with force alone. Rather, it is a collection of strategies and tactics aimed by any weaker group toward defeating a stronger enemy.

Not to be outdone by the 4GW theorists, writers offered a concept of "Fifth Generation Warfare" (Reed, 2008; Coerr, 2009) that incorporated information-age technologies including cyber attack that would "destroy or render an enemy's efforts irrelevant by any means." Near the turn of the millennium two Chinese military officers outlined what they called "Unrestricted Warfare" calling for any and all conventional and unconventional methods to attack both means and will (Liang and Xiangsui, 1999). Later, Reed summarized the generational theories as lying on three axes: *domains* of fighting, including not only the physical space of land, air, and sea, but also cyber space and political space; technological evolution of *adversaries* to include networks and "supra-combinations;" and the evolution of *objectives* from the destruction of armed forces to "attrition of will" and "implosion" (Figure 1.1).

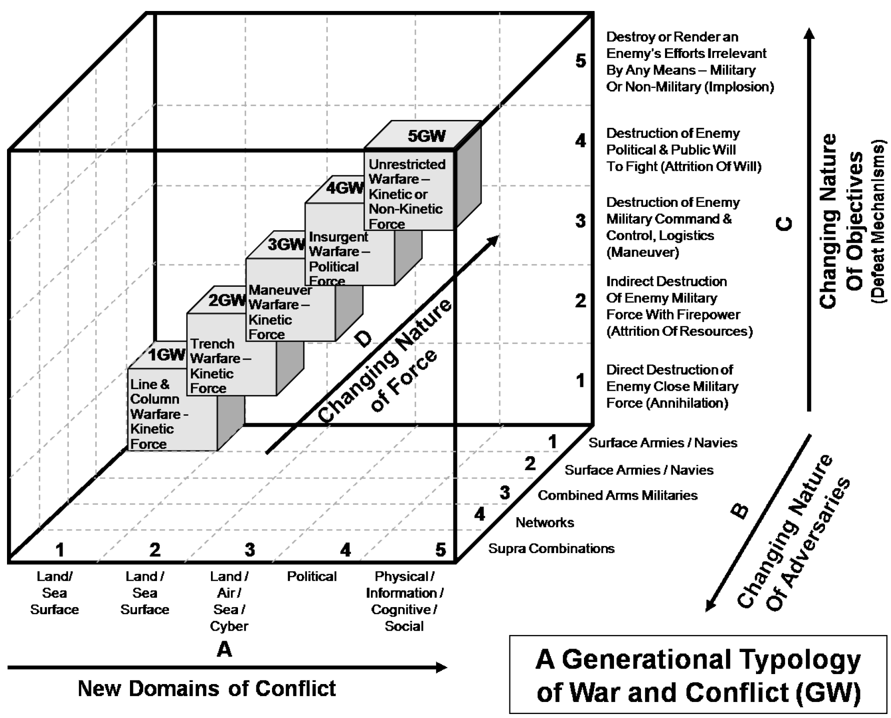


Figure 1.1 – Generational War Typology (Reed, 2008)

The additions of the Fifth Generation writers look a lot like more information-age technologies to enhance the tool kits of insurgents. They describe using military and extra-military means to attack both the enemy's will *and* capability to resist.

But are Fourth and Fifth Generation Warfare actually something different, or are they just "old wine in new bottles?" Insurgencies have been fought by combatants since ancient history, and common usage of the word "guerrilla" itself dates from at least the time of Wellington's campaign against Napoleon's forces in the Peninsular War (Liqueur, 1997).

The similarities between classic guerrilla warfare and 4GW are striking. The main difference appears to be that in classic guerrilla campaigns, communications were often primitive, and it was difficult to coordinate unified actions quickly among dispersed guerrilla units. The use of messengers was common in the Chinese Civil War, mainly because guerrillas needed to hide in isolated areas for security. Telegraph and radio allowed widely dispersed units to be able to coordinate their actions more quickly and effectively, but coordination required extensive time and preparation compared to today's standards.

While propaganda was a vital recruitment tool and was important to rally the people to the cause (particularly those who were undecided), dissemination of messages in classic guerrilla warfare depended on older technologies—printing and distributing leaflets, speeches by leaders, and "education sessions" in the villages. Pamphlets and other written material could be reproduced and distributed widely, but charismatic leaders had to rely on smaller audiences to deliver their messages in person. Later, radio, film, and television allowed distributing propaganda to a far wider audience. The effectiveness of the "first televised war" in Vietnam in part prompted American citizens to put pressure on their leaders to withdraw. This seemed to lend credibility to the idea that guerrillas could attack the enemy's will strategically. By the time the Fourth Generation theorists began publishing their ideas in the early 1990s, the world was in the midst of the information revolution. The increased effectiveness of propaganda harnessed with information-age delivery increased the speed and spread of the messages. No longer was it impossible to envision victory through defeat of fielded forces alone. Thus, authors analyzing post-WWII conflict married irregular tactics with the information revolution. They asserted that wars would be won on primarily through information by attacking the enemy's will to fight and called it 4GW.

The Fifth Generation theorists carried these ideas further. Hammes (2008) postulated that 5GW would be primarily "nets and jets", wherein information-age charged networks would spread ideas while jet transport would move people and unconventional weapons such as contagions. These networks would join disparate groups that shared the common goal of fragmenting the nation-state system (p. 23). Reed (2008) noted that with information-age communications, "… an opponent can dissipate his centers of gravity across the omnipresent battlefield so that they become virtually non-existent." In other words, like guerrillas, the Fifth Generation warrior would disperse in order to avoid presenting a target to his opponent, but could still tightly coordinate his actions with his comrades through information networks. Al Qaeda, the Madrid Bombers, and Hezbollah are all held up as examples of the extension of 4GW tactics into a 5GW future where targets are everywhere and everything (Couerr, 2009). Rather than massing troops that provide an actionable target for information-age forces, 5GW forces can remain dispersed while creating massed effects—flash mobs, photo opportunities, social media memes, and other "engagements of opportunity" to fight their opponents in battles for the mind.

The distinguishing characteristics of Fourth and Fifth Generation Warfare in comparison to CGW may therefore be thought of as unconventional tactics plus mobile communications and internet, all in order to marshal and magnify the military, social, and economic strength of the weaker combatant, and directly attack the will of the opponent to continue to fight. Psychological operations that exploit the enemy's will can be synchronized with terrorist attacks, global irregular actions, and military victories in the field, while economic actions provide needed supply to both combatants and quasi-combatants, who blend in with populations and exploit vulnerabilities of globalized society.

If 4GW and the irregular subset of 5GW are Mao's tactics with information-age communications, how much more effective are these operations versus the classic guerrilla actions that were fought without the benefit of mobile phone and internet? Is there a way to quantify the expected increase in effectiveness of 4/5GW operations over traditional guerrilla strategies and tactics?

Moreover, 4/5GW is fought against a capable enemy who *also* has the benefit of improved communications, plus the potential advantages of better network defense and cyber intelligence capabilities. Therefore, what is the relative balance of these increased capabilities? Would the increase of effectiveness from improved communications, coordination, and propaganda capabilities favor the insurgent side, or rather the technically advanced industrialized forces?

To try to answer these questions, a computational model was developed for comparison of classic guerrilla warfare with information-age warfare (Sink and Travis, 2019). Emergent behavior from simulation were used explore various themes in the civil war literature, such as the impact of differing terrain types, and the effect of grievance on recruitment and efficacy. The models were used to compare and measure the differences between 4/5GW and classic guerrilla warfare in terms of territory gained, time to victory, and identity of the victor.

Chapter 2 – Background

With the advent of the nuclear age, total war on the scale seen in the Second World War became unthinkable, at least by a consensus of the political leadership of the nuclear powers (Schelling, 1980) (Jervis, 1988). During the Cold War, an era of limited warfare returned somewhat unexpectedly following its long decline after the rise of Napoleon and mass national mobilization. During this period, the United States and Soviet Union competed in proxy wars with limited means for limited aims. In response, according to these theorists, 4GW developed and grew to counter the capabilities of the major powers. The American retreat from Vietnam and the Soviet withdrawal from Afghanistan were in large part due to the inability of legacy military forces (so-called "Third Generation" or "maneuver" forces) to deal with the tactics of insurgents fighting for their homelands (Summers, 1995) (Maley, 2009). These defeats of what many considered the world's premier military force prompted a reevaluation of every aspect of U.S. military art, and at all levels of conflict: from formulation of policy and grand strategy, to military strategy and operational art, and down to the level of battlefield tactics. These encompassed the entire spectrum or organization, training, and equipment. It was in this context that the idea of generations of war developed.

Concepts of generations of war (Table 2.1) gained currency in the late 1980s and early 1990s, as U.S. military education institutions sought to analyze and understand the unsatisfactory endings of military operations in the years following the allies' unambiguous victory in World War II. The stalemate in Korea, the defeat in Vietnam, the 1976 Mayaguez Incident, the 1980 Desert One fiasco, the 1983 bombing of the U.S. Marine barracks in Beirut, Lebanon, and the successful but flaw-ridden victory over Cuban quasi-military forces on the small Caribbean island of

Grenada, all contributed to a general feeling that there was something deeply wrong with organization, doctrine, training, or something else in the way that the U.S. military conducted operations.

Military authors looked back at how previous generations had successfully adapted to the changing nature of warfare. The U.S. Army had transformed itself in the years of the Civil War. In the beginning of that conflict, troops massed tightly to concentrate fire of inaccurate muskets. But by the end of the war, most soldiers were equipped with rifles that were accurate to over 200 yards, and the Gatling gun, an early precursor of the machine gun, had appeared on the battlefield. In the face of increasing lethality of the battlefield soldiers realized that they needed to disperse and find cover to survive. Units on both sides dug trenches in order to protect themselves. Trenches would become even more important in World War I, wherein heavy artillery and machine gun fire combined to make open ground even more deadly. The tank, invented and rushed into service toward the end of the Great War, allowed a new set of battlefield tactics, which were perfected in the 1920s and 1930s by experimenters of various nationalities. With armor restoring mobility to the battlefield and aircraft clearing the way, the theories of “maneuver warfare” were born, and remained standard doctrine in most militaries throughout much of the mid-to-late twentieth century.

Meanwhile, anti-colonial and other independence movements gained popular support. Rebels fighting organized governments realized that they could not match the military might of the great powers in conventional battles of the type seen in WWII and turned to a type of warfare that promises victory to the weaker side, if only they could persist and survive.

Table 2.1 – "Generational" Warfare

First	Line and column tactics. Organized military forces. Regular Drills in order to mass and synchronize musket and cannon fire.
Second	Firepower dominates the battlefield. Accurate fire by rifles, heavy guns, automatic weapons. Attrition of enemy forces through destruction.
Third	Armor restores maneuver to the battlefield. Tanks and planes attack near and far in the enemy's rear areas. Goal is disintegration of enemy's ability to command and supply forces.
Fourth	Blurring of lines between soldier and civilian, front and rear of battlefield. Protracted attrition, exhaustion of enemy. Goal is collapse of will.
Fifth	"Unrestricted warfare." Use of all means, conventional and irregular to attack enemy across physical, cognitive, cultural, and cyber domains.

Guerrilla Warfare

The power of guerrilla tactics against a stronger enemy, particularly one that is occupying the guerrillas' homeland, is buttressed by Clausewitz' observation that the defense is the stronger action in war (Howard, et al, 1984). Strategically, the defenders have time to prepare strong points, shore up weak areas, and move soldiers around in interior lines. But in an occupation, the occupier now must defend and hold his expanding secure areas. As the occupied area becomes larger, the occupier is spread thin. Thus, if the guerrillas can mass quickly in numbers superior to the forward outposts of the occupying forces, they can strike their opponents' small units quickly, and then just as quickly melt back into the population. When the enemy tries to bring in stronger units to mass and counter-attack, the guerrillas have disappeared.

Mao Tse Tung, writing in 1937 to rally his compatriots against the Japanese occupation of China, wrote a treatise on guerrilla warfare, patterning his ideas after Lenin (Mao, 1989). Mao's treatment stresses dispersion and self-sufficiency of forces, unity of effort even when there is no centralized command, and uniting the entire population in a struggle that uses all of the instruments of national power to fight the enemy. Mao's strategies were later adopted by Ho Chi Minh and Vo Nguyen Giap in first fighting the French and then the Americans in Vietnam (Giap, 1971). The Vietnam People's Army fought classic, protracted guerrilla campaigns that culminated in two conventional land attacks. The first attack in 1972 was blunted by Operation Linebacker I, but the second in 1975 succeeded in toppling the Republic of Vietnam government and unifying the country under the communists after the Americans' willingness to continue to support the South had ended.

Mao's tactics are summed up in his famous aphorism: "When guerrillas engage a stronger enemy, they withdraw when he advances; harass him when he stops; strike him when he is weary; pursue him when he withdraws" (Mao, 1989). The characteristics of Mao's guerrillas can be described as follows:

- Forces hold secure bases, far from the occupying enemy. Difficult terrain is an advantage to the guerrillas and a disadvantage to the occupying enemy.
- Guerrilla soldiers consist of lightly armed forces capable of rapid maneuver.
- Soldiers mass and concentrate only to attack—they disperse after the attack, to avoid presenting a target to the enemy.
- The primary goal is the preservation of the guerrilla forces' strength and the diminishing of the enemy's strength.
- Soldiers arm themselves by capturing enemy weapons.
- The entire population is mobilized through political propaganda, and supports the guerrillas with food, clothing, transport, and supplies. Guerrilla soldiers "hide in the open"

among the population during the day. “The population are the sea in which the guerrilla ‘fish’ swim.”

- Guerrillas fight from weakness, attacking and destroying small units, only until they are strong enough to mass large forces, fight, and then annihilate their enemy’s regular forces.

(Mao, 1989)

Fourth Generation Warfare

Like guerrilla warfare, 4GW is a strategy of weakness against strength, of attrition vs. annihilation, of exhaustion verses extermination. In 4GW, the overall aim is to attack the enemy’s *will* to fight (not necessarily his *capability* to fight), using all available means of power in coordination with the others. According to Mao, the strategic objective of the guerrilla is to weaken the enemy, bide one’s time and gather strength until one is strong enough to achieve a conventional victory over the enemy’s fielded forces. This was, in fact, the strategy of the North Vietnamese, who twice attempted large-scale military attacks with conventional forces. The first, in the spring of 1972, failed primarily due to the resistance of South Vietnamese army and American air forces (Haun, 2016). Once the Americans were gone, Hanoi succeeded on the second try in 1975 (Duiker, 1996).

On the other hand, 4GW theorists emphasize victory through collapse of the enemy’s willingness to continue the fight. Proponents of generational theories thus point to directly attacking the enemy’s will to fight as a characteristic of 4GW. Certainly, it is some observers’ view (e.g., Summers, 1995) on Vietnam, that Ho correctly had identified continued support of the United States to South Vietnam as the center of gravity of his war and aimed Hanoi’s informational and diplomatic efforts at the strategic level toward the end of getting the Americans to quit. In 4GW, however, propaganda and popular support take on outsized importance due to instant global communications.

Hammes (1994) described 4GW this way: "The move toward [4GW] is occurring in parallel with move into the information age—i.e., with the political, economic, and social changes affecting society as a whole—and the essential characteristics of this new form of warfare have been clearly illustrated in recent conflicts." 4GW has been described by various authors) as having the following features:

- Military forces are widely dispersed.
- Distinction is blurred between war and peace, between front and rear, and between civilians and soldiers.
- Years can pass between battles, or "battles" may spring up in rapid succession in response to political or social events.
- Non-linear battle lines appear, where it is difficult to distinguish between the battlefield and secure rear areas.
- Soldiers pose as civilians to avoid detection by enemy forces engaged in "nation building" or trying to "win the hearts and minds" of the population, then unexpectedly mass and attack.
- Suicide bombing is used as a tactic (Pape, 2006)
- Attacks and defending actions occur throughout the combatants' time and space, using not only military means, but also the exercise of psychological, cultural, diplomatic, and economic power.

- Attacks can be launched against an enemy's financial resources (such as oil fields in Mosul, Iraq) or psychological attacks can be directed at the enemy's population, in the form of images of dead children following an airstrike against a military target.
- Fixed facilities, whether they are broadcast stations, airfields, political centers, power generation or industrial sites, or military headquarters become vulnerable because information of their locations and functions becomes widely accessible.
- Success will depend heavily on impromptu decision-making by dispersed elements, "as lines between responsibility and mission [of the engaged forces] become very blurred."

Certain aspects of 4GW overlap with conventional warfare. First, "mission-type orders" are issued by commanders. Instead of issuing orders to move to a certain point on a map or to engage designated enemy formations, commanders are given the overall tactical objective and allowed freedom to determine the best path to support that objective with their assigned forces and equipment. This enables forces to respond effectively to the inevitable changing conditions on the battlefield that characterize the "friction" of war (Clausewitz, 1976). Thus, there is a premium placed on "the ability to concentrate suddenly from very wide dispersion, and selection of subordinates who can manage the challenge of minimal or no supervision in a rapidly changing environment" (Hammes, 1994).

Secondly, there is decreased dependence on centralized logistics. Soldiers are dispersed and use the population to equip and feed themselves and then rapidly mass to attack, and just as rapidly disperse to avoid presenting a target to a technologically advanced enemy.

Third, the 4GW warrior leverages the principle of maneuver. Rather than fighting the enemy on a linear front, the 4GW practitioner seeks to find the weak points of the enemy defenses, and either bypass them or destroy them to allow freedom of maneuver across the enemy's battlespace.

Finally, the main goal becomes one of collapsing the enemy internally as opposed to destroying his armed forces—an example is the strategy of the Viet Cong and North Vietnam of collapsing the political will of the leadership of the United States during the Vietnam war.

Other academics took up the cause of 4GW. Candace DeRussy (2003) wrote that 4GW was characterized by "a lack of definable battlefields, by groups acting not necessarily under the direct control of a foreign government, and by its transnational nature. It does not rely on massed manpower, massed firepower, or maneuver, as in, respectively, First, Second and Third Generation Warfare." Canals (2009) used present-day Jihadist movements as a paradigm for 4GW. He pointed to an interview with Abu Ubeid al-Quarashi, "one of the closest aides to Bin Laden" who described Al Qaeda doctrine as 4GW and urging fellow jihadists to adopt it (p. 897).

In response to numerous critics (Stewart, 2004; Evans, 2005; Echevarria, 2005), proponents further refined the definition of 4GW: "4GW uses all available networks – political, economic, social and military – to convince the enemy's political decision-makers that their strategic goals are either unachievable or too costly for the perceived benefit. It is rooted in the fundamental precept that superior political will, when properly employed, can defeat greater economic and military power. 4GW does not attempt to win by defeating the enemy's military forces. Instead, combining guerrilla tactics or civil disobedience with the soft networks of social, cultural and economic ties, disinformation campaigns and innovative political activity, it directly attacks the enemy's political will" (Hammes, 2005). Informational power can be used to directly attack the enemy's will at the strategic level. "Whether the anti-land mine campaign or Zarkawi's terror campaign in Iraq, the Internet provides an alternative channel for high-impact messages unfiltered by editors or political influence. It can also be used to raise money." Meanwhile, cultural power undergirds the combatants' support by providing resources for people's physical needs. In this way, the combatants cultivate loyalty, and in return, receive substantial support from large segments of the civilian population that act as logistics providers, intelligence sources, and communications outlets (Manwaring, 2012).

Fifth Generation Warfare

Hammes (2007) began writing about a so-called Fifth Generation of warfare even before the debate surrounding Fourth Generation Warfare had settled. According to him, the distinguishing characteristics of 5GW were communications networks between non-state actors, innovative organizations, and unconventional weapons. On the other hand, Coerr (2009) focused on post-9/11 attacks against American power by loose coalitions of terrorists and other transnational actors, such as Al Qaeda and Hezbollah. To Coerr, insurgencies characterize 5GW as much as if not more than unrestricted large-scale battle between great powers. These insurgences are directed by "ad hoc groups linked to one another through webs of religion, tribe, race, family, and ideology that Americans cannot penetrate." He sees global jihad as the main face of 5GW. "5GW irregular forces…revolve around the central belief of an irregular actor, bound by the goal of a unifying belief that we cannot see, and floating freely and without apparent pattern, without regard to names and lines on a map" (p. 66).

Reed (2008) described the rise of the Fifth Generation in this way: "The impact of the Information Age and of globalization on the postmodern era of war is both comprehensive and profound. It is characterized by a number of outcomes: The decline of the political, economic, social, technological, and warfare monopolies waged by nation-states; the increase in the number of non-state entities capable of competing with nation-states by waging fifth generation warfare to achieve their own self-interests; and the elimination of boundaries so that the entire world is now the battlefield in a broad sense." Therefore, one could think of 5GW warfare as comprising of shifting global coalitions that have instant communications with each other and can cause global effects without using kinetic or traditional military means. Thus, the realm of 5GW can be conceptualized as global battlefield upon which struggle for power is played out across a range of conventional and unconventional actions culminating in the use of all dimensions of power (military, economic, cultural, etc.) to influence one's adversary to produce a desired policy. Reed's definition of 5GW is by far the broadest, incorporating all of the aspects of unrestricted warfare and adding his own interpretations (e.g., "supra- combinations" of multiple force, domain, objectives, and adversaries).

Whether or not one agrees with Reed's characterization of 5GW as warfare across multiple dimensions of forces, adversaries, objectives, and domains, the U.S. military has created doctrine that recognizes the importance of information age technologies and tactics. The Joint Concept for Operating in the Information Environment asserts that, "To produce enduring strategic outcomes that hinge on perceptions, attitudes, and other elements that drive desired behaviors, the Joint Force must operationalize its application of informational power. A better characterization of the informational, physical, and human aspects of the security environment is required to expose and leverage the interdependencies between them. Because perceptions and attitudes inform behavior, the Joint Force must treat them as 'key terrain'" (Joint Chiefs of Staff, 2018, p. ix). Like Reed, the U.S. military leadership see an information environment (Figure

2.1) that encompasses physical, informational, and cognitive dimensions of conflict (but they omit the social, including those elements in the cognitive or informational domains).

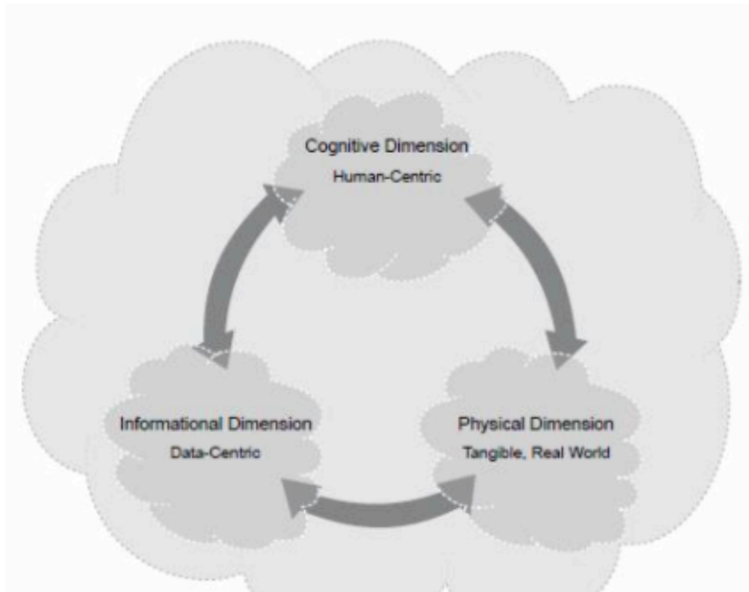


Figure 2.1– The Information Environment (Joint Chiefs of Staff, 2018)

Thus, the U.S. military leadership envisions a future where information age technologies form messaging strategies that influence various audiences to create an environment favorable to victory.

Economics

Curiously, the 4GW and 5GW theorists generally give the economic instrument of national power only cursory treatment, or it is grouped together with elements of cyber warfare. This underestimates the potential of using economic strategies to complement, or in some cases, to lead a counter-insurgency effort. Military strategists are conversant in the terminology "DIME," which means the types of actions and means of national power: Diplomatic, Informational, Military, and Economic (Perla, 2006). The section of the U.S. National Security Strategy (2017) entitled “Tools of Economic Diplomacy” recognizes that, “Prosperous states are stronger security partners who are able to share the burden of confronting common threats.” Although discussion on economic tools in war often focuses on using economic sanctions as tools (e.g., “Deploy economic pressure on security threats…”) (p. 34), the strategy also recognizes that ,“The United States must use its diplomatic, economic, and military tools simultaneously when assisting aspiring partners [and] place a priority on economic support that achieves local and macro-economic stability, helps build capable security forces, and strengthens the rule of law” (p. 40).

Research supports the importance of economics in combating civil violence and rebellion, particularly when economic grievance is the central issue of the conflict. Both in “Phase 0” (advisory) support to a struggling government, as well as in post-war stabilization efforts, economic development objectives can play a major role in reducing the “demand for violence,” particularly in situations where political stability is fragile. Yet the opposite is also true—lack of constructive economic alternatives can incentivize violence. To cite one example, the rapid draw down of forces and inadequate foreign aid after the U.S. invasion of Iraq left a stabilization force wholly inadequate to deal with post-conflict instability as thousands of former regime soldiers and workers were suddenly left without constructive employment (Abdollahian, et al, 2009). Planning for an increased number of stabilization forces and amount of economic aid early on could have made a significant difference in the stabilization path of the country (Figure 2.2)

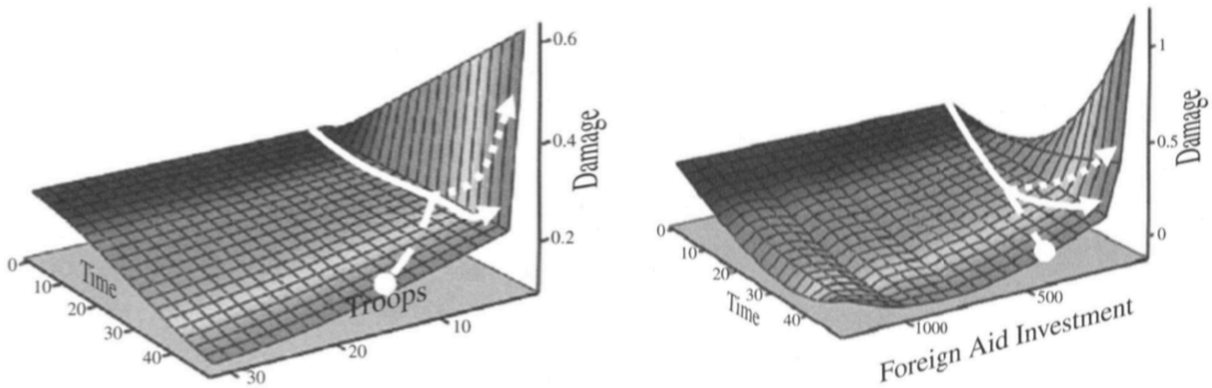


Figure 2.2 – Iraq, Effect of Troop Strength Investment and Foreign Aid Investment on Damage (Abdollahian, et al, 2009)

Humanitarian and civic assistance (e.g., providing medical, dental, and veterinary care; construction of vital water supplies, sanitation, and transportation infrastructure; and repair and improvement of public facilities, etc.) particularly projects that employ and occupy local workers, can be effective components of an overall civil violence reduction strategy that attacks the causes of instability (Army, U.S., 1990). Moreover, economic incentives are often central to ending civil wars, particularly when there is a "spoiler" problem, where one or both parties have strong incentives to continue the conflict (Stedman, 2002). Yet such use of economic incentives must be nuanced and tailored to the situation at hand. As Rosenberger (2019) puts it, "[T]he transition from civil conflict to a market democracy is full of pitfalls: promoting democratization and marketization has the potential to stimulate higher levels of societal competition at the very moment when states are least equipped to contain such tensions within peaceful bounds." He points to the New Silk Road initiative as a potential example for stabilization in Afghanistan, but the effort was defunded before it really got off the ground. Later, China emulated the project in its Belt and Road Initiative, but the U.S. apparently didn't want to compete in this arena (p. 6).

While Reed expands on the changing nature of conflict domains and objectives, one has to read between the lines in his description of the cultural domain and the levels of objectives (economic objectives typically reside at the policy and strategy levels of objectives) to tease out the potential of the economic instrument. About the most specific that Reed gets on economic power is when he writes about Supra-Domain Combinations: "…new forms of warfare become possible, including for example financial warfare, environmental warfare, media fabrication warfare, science and technological warfare, cultural warfare, psychological warfare, religious warfare, or any combination thereof…" (p. 698).

Therefore, the models in this study do not attempt to simulate an economic sanction or incentive structures in 4/5GW. Not only do the authors of 4GW and 5GW concepts downplay the economic instrument, such modeling would be highly situationally dependent. On the other hand, the information environment is highly relevant, since the 4GW and 5GW theorists look at communications and information networks as central to modern warfare. One economic variable is modeled in the simulations, and that is the unemployment rate. This is primarily used as a proxy for economic deprivation, which is present in many theories of civil war. However, its purpose is NOT to model poverty per se, but rather generate variation in the models and provide a scalable statistic that can be compared to historical cases of insurgency. The differences between the constructs are summarized in Table 2.2, below.

Classic Guerrilla Warfare is modeled as an insurgency in country, in which the terrain and degree of urbanization can be varied. Government forces are depicted as Blue agents and Insurgent forces are Red agents. Green agents are civilians but can be recruited to either Pink

Table 2.2 – Summary of Classic Guerrilla vs. Fourth/Fifth Generation Warfare

	Classic Guerrilla	**Fourth Generation**	**Fifth Generation**
Objective	Enemy capability	Enemy will	Enemy will/capability
Means	Military/Propaganda	Military/Informational	Military/Info/Cyber
Strategy	Attrition	Attrition	Attrition/Irrelevance
Tactical Aim	Destroy/Capture arms	Destroy Networks	"Supra Combinations"
Tactics	Irregular	Irregular	Regular/Irregular
End Game	Conventional attack	Enemy exhaustion	Enemy Implosion

agents (active insurgent supporters) or Cyan agents (active Blue supporters). Reds and Blues can be recruited from Pinks and Cyans, respectively. The simulation starts with the government forces in the cities and the insurgent forces in the countryside. As the simulation progresses over time, forces move to engage in battle when they believe that they are locally superior to their opponents. In this way, the force ratios and the percent of territory occupied by the respective forces are measured and compared. Victory is determined, somewhat arbitrarily, when one side or the other had occupied ten percent more territory and has ten percent more forces than the opposing side.

So then, what exactly is the model here that is compared to CGW? For the purposes of this study, a 4/5GW agent-based model has been created that combines salient features of both 4GW and the irregular subset of 5GW. This combined 4/5GW model is conceptualized as *irregular warfare with information age communications.*

- Speed and fidelity of communications is increased in 4/5GW model.
- Lethality is increased for both sides, but especially the government forces, as precision guided weapons are prolific on the battlefield and captured by or supplied to the insurgents.

- Propaganda is modeled in both the CGW and 4/5GW, but its effectiveness is amplified by an order of magnitude in the 4/5GW model. Its frequency of distribution or repetition is also increased.
- Terrorist attacks in the form of suicide bombing, a modern "innovation," is modeled in the 4/5GW version.
- Mobility is different in the two models. Paradrops can be selected on/off in the CGW model, while air movement of troops is standard in the 4/5GW model.
- Finally, third-party interventions are modeled in 4/5GW. These can be adjusted by the regular appearance of government reinforcements and adjustment of the "spawn rate"—the rate at which these reinforcements are introduced into the environment.

The differences between the two models is summarized in Table 2.3, below. The actual numerical differences in the various parameters is given in the technical description of the models in Chapter 4.

Table 2.3 – Differences Between the Two Agent-Based Models

	CGW	**4/5GW**
Speed/Fidelity of Communications	Standard	Increased
Lethality	Kill Probability 50%	Kill Probability 70% / 90%
Propaganda	Standard	Increased Rate and Effectiveness
Terrorism	None	Suicide Bombers
Mobility	Paradrops Selectable On/Off	Paradrops/Helidrops Standard
Third-Party Intervention	Notional	Adjustable by Spawn Rate

The next chapter reviews the literature of agent-based models of insurgency relevant to this project.

Chapter 3 – Literature Review

The literature relevant to this study includes the Fourth and Fifth Generation material discussed in the previous chapter. 4GW and the irregular subset of 5GW are fundamentally based on insurgency. Although the problem modeled in this research is primarily military, concepts are drawn from some of the more well-known literature in civil violence, civil war and insurgency, specifically the impact of poverty and perception of government legitimacy. The actual *causes* of civil war, while important to the study of the topic of guerrilla warfare, are treated here as an overview to set the context. While this literature is highly important to several subfields of international politics, this research is only tangentially related to the question here, which is comparing and contrasting the *conduct* of CGW with 4/5GW.

Models of civil violence are briefly reviewed to provide context. The literature on simulation, wargaming, and agent-based models is relevant, so it is reviewed here. In particular, the agent-based simulations of civil violence and insurgency extent in published research are treated in some detail, mainly to contrast them with the approach taken in this study.

Causes of Civil War.

The literature of the causes of civil war is beyond the scope of this research, but a brief review is in order, since several concepts such as government legitimacy and unemployment are incorporated in the models. The causes of civil war have been extensively studied and well documented in other works. Cioffi-Revilla and Rouleau (2010) divide the schools of civil war causation into three general categories: relative deprivation, the cultural explanations, and economic or opportunity literature. Relative deprivation theorists generally assert that poverty and lack of development are causal to conflict. Proponents of cultural explanations focus on ethnicity, national, and religious differences as foundations either separately or with deprivation factors. Economic or opportunity theories state that factors favoring the opportunity to rebel are as important as the motivational factors, especially where such opportunities are extended to how easily resources are obtained, or how easily political instability and state failure can be exploited.

The relative deprivation school is exemplified by Gurr (1970) and Morrison (1971), while Gurney and Tiery (1982) question the deprivation scholars for not explaining why instability is met with civil violence in some cases but not in others. The culturalists—mainly Deutsch (1953), Anderson (1983) and Gellner (1983) were augmented and critiqued by Horowitz (1985), Connor (1994), and Huntington (1996). Most well-known are probably Fearon and Laitin (2003) and Collier and Hoeffler (2004). Fearon and Laitin explained civil war as relating to particular aspects of a state that facilitated opportunity for insurgency, mainly poverty, political instability, rough terrain, and large populations. Collier and Hoeffler (2004), emphasized that the association was strongest with accessible resources and weak and unstable governmental structures. Collier and Hoeffler analyzed a sample of civil wars from 1965-2004 found that in general, the likelihood of civil war is resistant to motivational explanations such as poverty or ethnic strife. Rather, they argued that civil war is most likely to occur where it is most feasible. Nathan (2005), however, argued that Collier's and Hoeffler's analysis suffers from selection of inappropriate proxies and lack of alternative explanatory variables. Cederman and Girardin (2007) generally supported Fearon's and Laitin's conclusions while at the same time criticizing their research methods. Collier and Sambanis (2005) generally support the economic/opportunity-based explanations, analyzing case studies of civil war in Africa.

More recently, Djankov and Reynal-Querol (2010) revisited the question of whether poverty is associated with civil war, comparing a cross-section of countries looking at the difference between pooled OLS and Fixed Effects models. They found that once the impact of colonial histories of some countries were considered the effect of per capita income on civil war disappeared. "[Once] historical variables are included in the civil war regression, per capita income does not have an explanatory effect on civil war" (p. 1040).

As for government legitimacy, DeRouen and Sobek (2004) found that "An effective state bureaucracy undermines the rebels, but a strong government army does not necessarily enhance the government cause." They also noted that forest cover hinders rebels, while mountain cover tends to aid insurgents (Fearon and Laitin identified rough terrain as an explanatory factor). On the other hand, Kugler, et. al. (2012) argue that it is not government legitimacy nor economic performance but rather political performance that is key to understanding relative power in warfare. They note that "developing societies extract lower levels of revenues but are capable of mobilizing far more because there is so much slack in their revenue extraction. Under stress, successful developing societies such as…North Vietnam in the 1960s, were able to multiply their 'normal' capabilities by tapping new sources of revenue" (p. 92). The authors show how that even when pitted against the much higher GDP for South Vietnam, North Vietnam was able to better mobilize its population and extract and distribute resources during the war years, even when including the years 1965–1969 when U.S. military support was at its height. But political performance per se is not included in the model in order to keep the complexity manageable.

Rather, government legitimacy is used as a common variable to capture both popular support and political performance of the government.

Generational Warfare.

In addition to the works on generational warfare described in the previous chapter, some others are worth noting. William Lind is generally considered as the originator of the concept, publishing two articles (Lind, 1989, 2001) in the U.S. Marine Corps' professional journal. Hammes (1994, 2005) was prolific on the topic, publishing several articles, as well as a book (2006) on 4GW and an article (2007) on 5GW. As writings on 4GW proliferated, Karp (2010) organized and surveyed the literature, compiling writings of both supporters and opponents of the concept of 4GW, including Lind, Hammes, Echevarria, and others. The critics focused on the close similarities of 4GW with classic guerilla warfare (Freedman, 2010) or the irrelevance of the threat (Luttwak, 2010), while proponents emphasized the changing security environment and proliferation of "non-trinitarian warfare" (Van Creveld, 2010), meaning a non-Clausewitzian conception of war, or the success of the ongoing insurgency in Afghanistan in bypassing the need to build up for a conventional endgame (Chin, 2010). The terms 4GW and 5GW have been incorporated into the lexicon of military scholarship (Thornton, 2005) (Perle, et al, 2006) (Strakes, 2007) (Junio, 2009) (Williamson, 2009) (Theile, 2013) and usage has become common. However, the debate as to the exceptionality of Fourth (and Fifth) Generation Warfare continues.

Modeling Civil Violence.

Several works on computational modeling of civil violence stand out in the literature. Lemos, et. al. (2013) surveyed agent-based models of social conflict, civil violence and revolution, including Epstein's model of civil violence (2002), the EMAS civil violence model (Goh et al., 2006), Kim and Hanneman's model of worker protest by (2011), Davies, Fry and Wilson's model of the London Riots (2011), Mackowsky and Rubin's model of centralized institutions, social network technology and revolution (2011), and a model of crime and violence in urban settings (Fonoberova et al, 2012). Table 3.1 below summarizes these models.

Lemos' agent-based legitimacy model (Lemos, et al, 2016) looked at feedback mechanisms for government legitimacy in civil violence and expanded in detail that aspect of Epstein's model. It was used to test theories of both homogenous support ("all citizens share the same perceived legitimacy") and heterogeneous ("where perceived legitimacy is an individual attribute"). The authors concluded that all of the models deepened the understanding of the importance of legitimacy feedback mechanisms in rebellion, but that "simulations with the exponentially decaying 'system support' function produced solutions with an initial period of calm with occasional small episodes of violence and constant legitimacy, followed by a large upsurge of violence and a sudden drop of legitimacy, and intermittent bursts of rebellion afterwards…This pattern provides an explanation for the phenomenon of apparently stable authoritarian regimes suppressing small bursts of rebellion and then facing a massive unexpected uprising, after which they struggle to dominate rebellion and never recover their initial legitimacy" (Lemos, et al, 2016). Sub indicators for modeling legitimacy feedback and their relative weights is shown in Table 3.2, below.

Table 3.1 – Summary of Agent-Based Models of Social Conflict, Civil Violence and Revolution (Lemos, et. al. 2013)

Author(s)	**Model Type**	**Social context in agents' specification**	**Agent rules, movement**	**Main results**	**Scales (space, time)**	**Observation and Empirical validation**
Epstein et al. (2001), Epstein (2002)	Civil violence	No	Simple threshold-based, random	Intermittent bursts of rebellion, deceptive behaviour, effect of variable legitimacy and #cops	Global (society) Indefinite	No
Doran (2005)	Guerrila warfare	No	Simple rules	Spatial spread, time variation and outcome of conflict	Global (society) 32-cell grid	No
Goh et al. (2006)*	Civil violence	No	Simple threshold-based, rule-based	Group effects, purposeful movement, more realistic protester/ police interaction	Global (society) Indefinite	No
Kim & Hanneman (2011)*	Worker protest	No	Simple threshold-based, random	Intermittent bursts, grievance as function of RD	Indefinite Indefinite	No
Davies et al. (2011)	Riots	Yes	Simple and determined by utility, determined by utility	Three step contagion/site selection/police interaction model, realistic results, validation	London area, five days	Yes
Mackowsky & Rubin (2011)	Revolution	No	Simple, no movement	Cascade of preference revelation, general mechanisms of social & institutional revolution, influence of ICT	Global (society) Indefinite	No
Fonoberova et al. (2012)*	Urban Crime and violence	No	Simple rule-based, random	Discussion of arrest probability function, agents with fixed state and difference between large and small grids	Global (city size) Indefinite	Yes

*models based on Epstein's model

Table 3.2 – Sub indicators, weights in Gilley's (2009) legitimacy score and related ABM variables selected for modeling legitimacy feedback (Lemos, et al, 2016)

Indicator	Subtype	Weight	Related variables
Satisfaction with democratic development	Justification	$\frac{1}{12}$	$\frac{n_{\text{quiet}}}{N}$
Evaluation of current political system	Justification	$\frac{1}{12}$	$\frac{n_{\text{quiet}}}{N}$
Satisfaction with operation of democracy	Justification	$\frac{1}{12}$	$\frac{n_{\text{quiet}}}{N}$
Use of violence in civil protest	Justification	$\frac{1}{4}$	$\frac{n_{\text{active}}}{N}, \frac{n_{\text{fighting}}}{N}, \frac{n_{\text{jailed}}}{N}$

N is the total number of citizens, and n_{quiet}, n_{active}, n_{fighting}, and n_{jailed} are the number of citizens in each of the four possible states.

Figure 3.1 shows the ABM structure for their model in class diagram form, showing the different classes of agents. The description is, "Class diagram for the 'observer,' 'citizen,' and 'cop' agent types in the NetLogo implementation. The 'observer' and 'turtle' agents are specific of the NetLogo system. The 'citizen' and 'cop' agent types are subclasses of the generic NetLogo 'turtle' agent type. The agents' attributes and methods that result from extensions or modifications of Epstein's model are marked by an asterisk" (p. 116).

Cioffi-Revilla and Rouleau's MASON RebeLand (2010) is a platform for exploring the reaction of a population to differing conditions of government performance and societal/political stress—how rebellion breaks out. It looked at two questions: first, "How does a polity respond to various levels and combinations of societal stress and governmental performance?" Second, "How can insurgency, domestic political instability, or…state failure emerge bottom-up in a society?" The authors note that "shifts in public moods, onset of insurgency and its subsequent development, and government crises and state failure episodes…always occur as emergent phenomena, not as directly hard-wired processes or events, and consistently across all…scenarios." In other words, RebeLand is universally capable of producing these phenomena as a result of its own endogenous dynamics, as a generative computational theory should"

(Epstein 2006). Therefore, the model is useful in looking at how government legitimacy and rebellion are related.

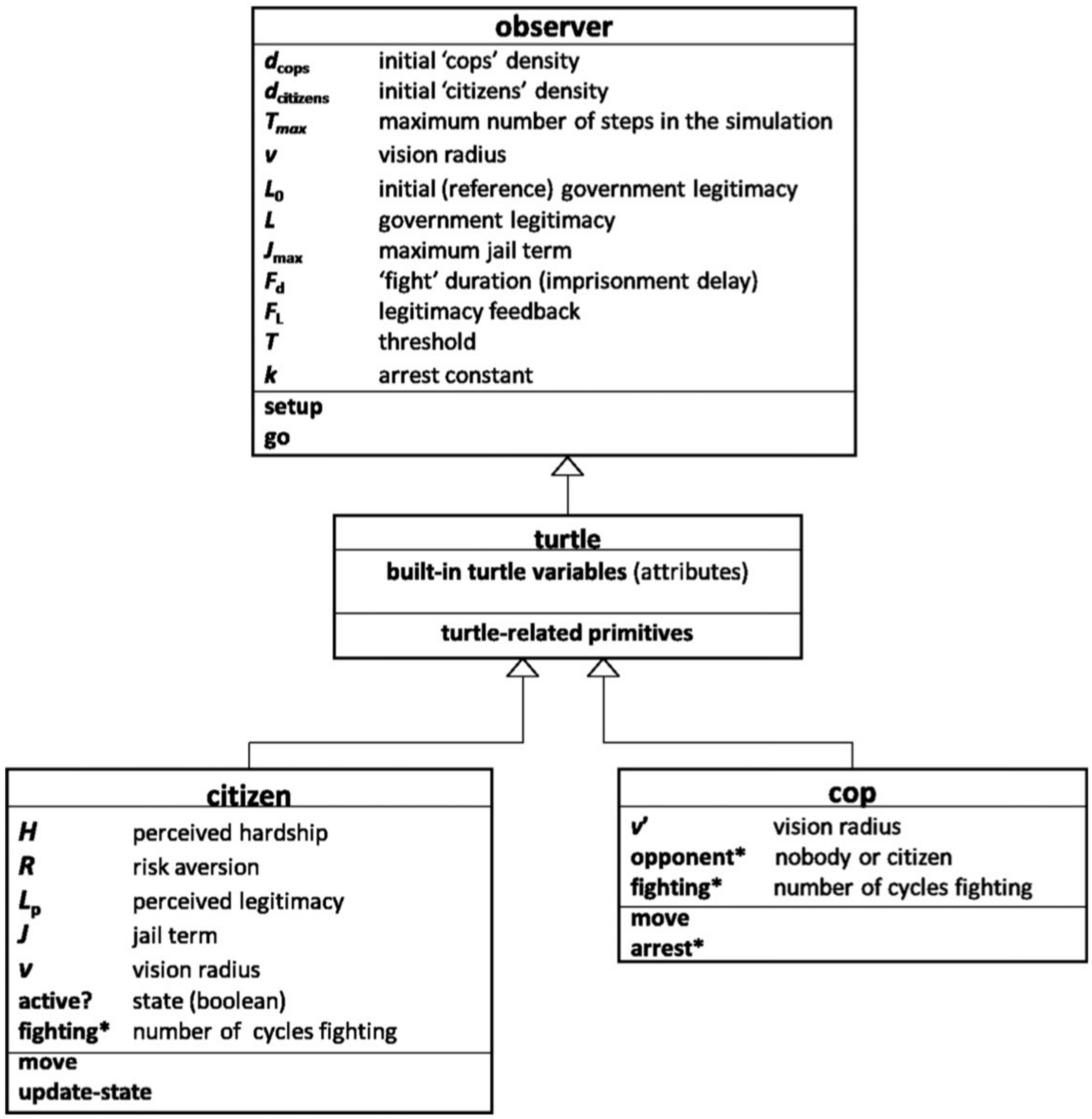


Figure 3.1 – Class Diagram for Model Exploring Government Legitimacy Mechanisms (Lemos, et al, 2016)

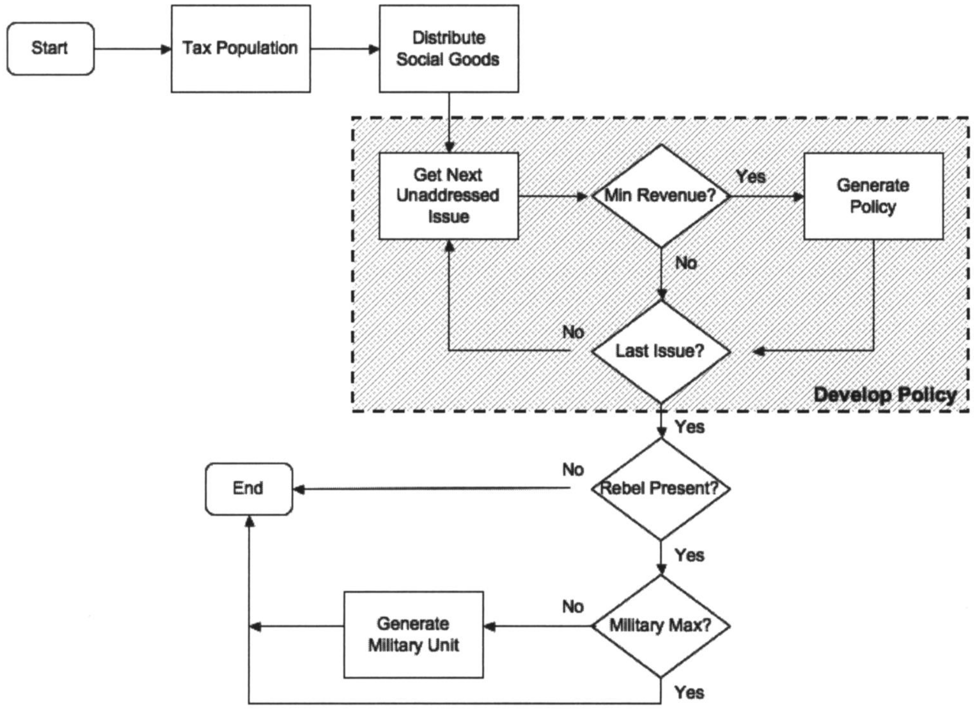


Figure 3.2 MASON RebeLand Main Simulation Loop from the Perspective of a City

In the MASON RebeLand simulation, agents run different routines depending on their position and interests in the world. The general population agents interact differently than the city agents and the agent representing the State (Figure 3.2, above). Here the cities compete for issue attention from the state and must tax the population in order to gain resources to distribute. They must generate military units in order to defend the city from rebel units.

The entire simulation runs within a notional socio-economic environment as well (Figure 3.3). "Issues enter the environment with a user-defined issue onset rate, a log-normal decay rate, and a power-law distributed magnitude. This allows users to define the level of stress a government will probably face in a given simulation run" (p. 38).

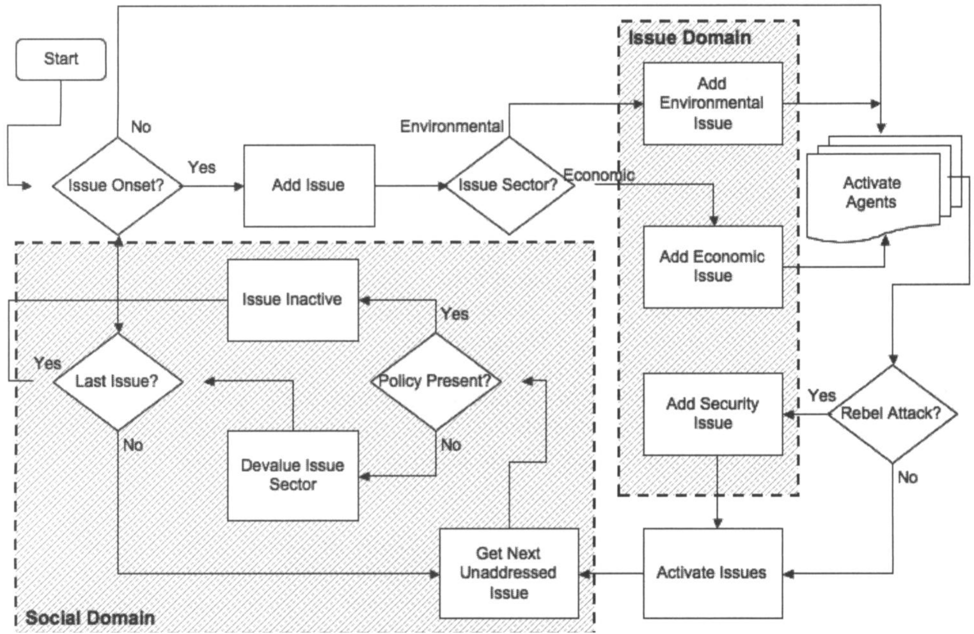


Figure 3.3 – MASON RebeLand Main Simulation Loop from the Perspective of the Socio-Economic Environment

Over a period of several years in the first decade of the 21st century, the Center for Naval Analysis investigated using Fourth Generation Warfare concepts in wargaming (Perla, et al, 2006). Although wargames often contain computational elements, they typically rely on human players to make “moves” based on their strategies and the available information provided by the game controllers. Several iterations of wargames were developed, including “Pirates of the Fourth Generation,” and “Granite Island Online,” where two networked coalitions struggle for supremacy. Their research focused primarily how to incorporate 4GW concepts into military wargaming. Although somewhat limited by the overlaying of 4GW concepts on previously developed 3GW wargames (Figure 3.4) the authors gained insights and made recommendations into future wargame design. Main emphasis was on incorporating an irregular construct where distinctions between combatant and non-combatant and front and rear are blurred—in short, the characteristics of irregular warfare.

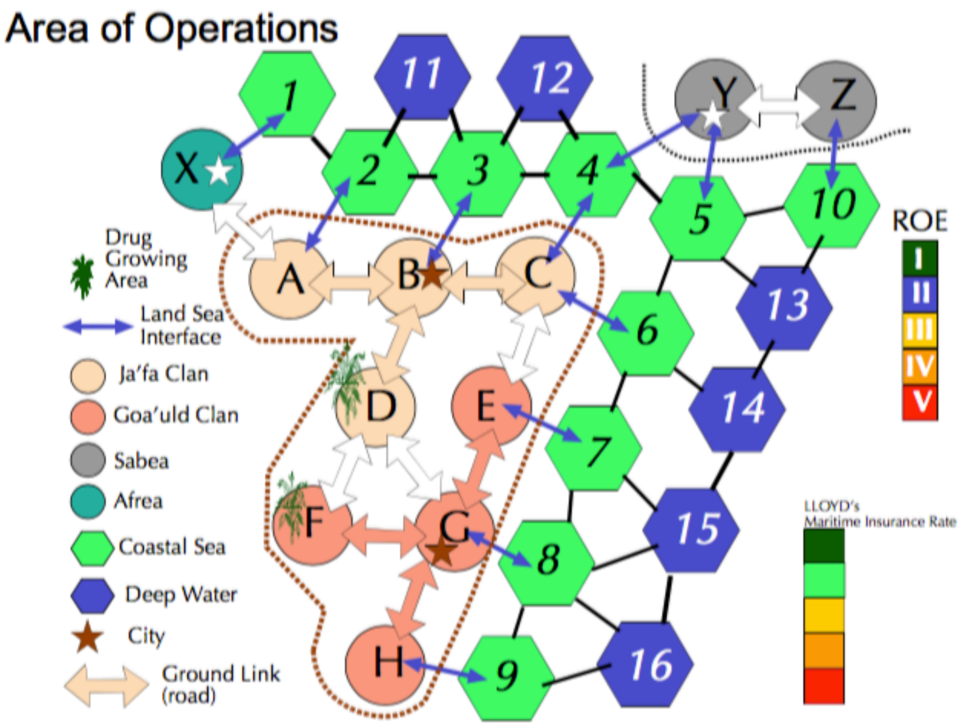


Figure 3.4 – Physical Game Space for Center for Naval Analysis 4GW Wargame (Perla, et al, 2006)

<u>Models of Insurgency/Guerrilla War.</u>

There are several computational models of insurgent warfare with different emphasis on different factors in the open literature surveyed by Cioffi-Revilla and Rouleau (2010): (Cederman, 2003) (Cioffi-Revilla and Gotts, 2003) (Bigbee et al, 2007) (Bennett, 2008) and (Bhavani et al, 2008). The two most well-known agent-based models of guerrilla warfare are the Iruba model of guerrilla war (Doran, 2005), and Martinez and Fitzpatrick's Agent-Based Model of Insurgency Warfare (2011).

Computer scientist Doran saw his Iruba model as an extension to historical analysis, and it was one of the first attempts to simulate guerrilla warfare using an agent-based framework. Victory in the model is determined solely on the basis of numbers of combatants—either the guerrillas are annihilated, or they achieve numerical superiority (Figure 3.5).

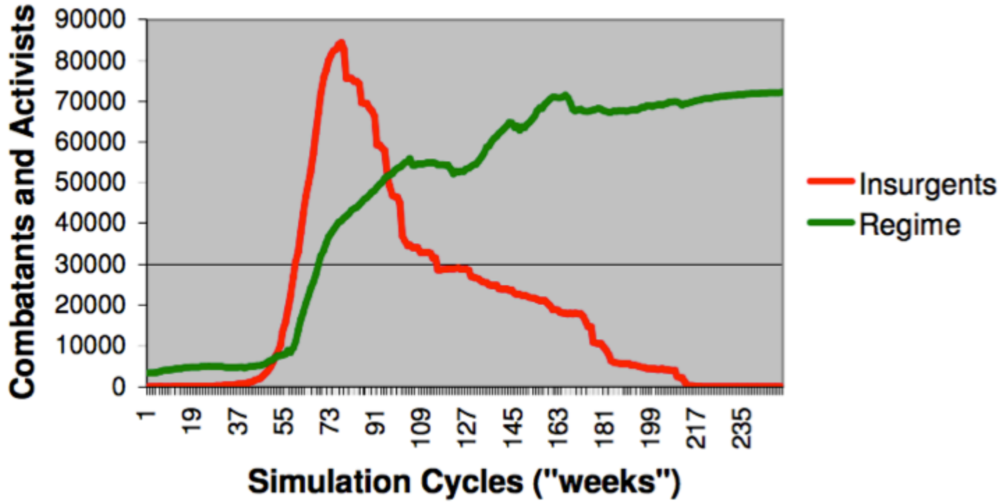


Figure 3.5 – Iruba Model Output Showing Numbers of Forces Over Time (Doran, 2005)

Part of Doran's motivation for developing Iruba was to test Guevara and Debray's (Beckett, 2001) theory of "foco," which holds that "even a very small dedicated group of insurgents will succeed provided that they have a political as well as military strategy, and provided that there is a significant level of initial support in the population at large" (Doran, 2005). In Doran's model, "foco" is unreliable (increasing levels of initial popular support do not reliably lead to victory), but that increased mobility and recruitment were the best indicators for guerrilla success. In fact, recruitment was more important than military proficiency. Finally, Doran found that the government's chances of success increased if they proceeded with an "all-out attack" early in the evolution of the war to thwart the insurgency at its onset. Doran also made special note of the methodological problems inherent in agent-based modeling guerrilla warfare and limitations of validating a model with such a wide range for parameters, as well as the positive feedback loop inherent in insurgency ("increasing insurgent numbers make insurgent success more likely, which increases population support for the insurgents and hence recruitment to and the numbers of the insurgents").

Table 3.3 - Impact of initial guerrilla band size on insurgent success rate. (Doran, 2005)

Initial guerrilla band size	30	35	40	45	50	55
Insurgent success (%)	5	28	58	79	86	90
Insurgent success (%) if regime force concentration	3	23	45	77	83	80

In Table 3, the impact of initial guerrilla band size is compared to insurgent success, where success is defined as the total insurgent force growing to more than 100,000 members. "For comparison, at the outset of his Cuban insurgency Castro initially had 81 followers, who were almost immediately reduced to about 20 in an attack by regime forces. The results…indicate the unreliability of *foco* theory as propounded by Guevara and Debray. In fact, most insurgencies inspired by *foco* theory do seem to have failed (Beckett, 2001, p. 171)."

Table 3.4 - Impact of insurgent attack effectiveness and insurgent recruitment efficiency.

		Attack Efficiency		
		1.0	1.5	2.0
Recruitment Efficiency	1.0	58	68	68
	1.5	73	86	90
	2.0	94	95	97

In Table 3.4, the attack efficiency is shown on the horizontal axis, while the recruitment efficiency is shown on the vertical axis. In Doran's words, "the results…suggest that effective recruitment is more important than military skills."

Martinez and Fitzpatrick's agent-based model (2011) more comprehensively modeled the insurgent environment. They constructed "a society of agents who are interconnected in an established social network. Each agent in this network engages in political discourse with other agents over the legitimacy of the existing government." Agents can either support the insurgency or government, or they can remain neutral. In fact, this project used Martinez and Fitzpatrick's recruitment sub-model, where agents can be recruited to be either combatants or supporters of either side.

The M&F model examined five different strategies for the agents (Table 35): *attack and retreat*, the classic guerrilla tactic; *collateral damage*, "based on the assumption that the enemy will over-respond if they are attacked"; *suicide*, where insurgents surround themselves with counter-insurgents and then kill themselves and all individuals within a given radius; Improvised Explosive Device (IED), where insurgents hide and then explode a bomb when sufficient enemy are near; and a conventional warfare strategy.

Table 3.5 – Martinez and Fitzpatrick (2011) ABM Strategies

Attack and Retreat Strategy	Prototypical guerrilla warfare strategy in which the attackers attack their enemy and quickly retreat, avoiding brunt of COIN reaction.
Collateral Damage Strategy	Purpose is to get the counterinsurgents to inadvertently kill agents not directly involved in combat.
Suicide Strategy	Insurgents surround themselves with COIN agents then commit suicide by blowing themselves up. Kills all individuals within a given radius of the suicide bomber.
Improvised Explosive Device Strategy	Insurgents position an IED and detonate a bomb when sufficient COIN agents are within the kill radius.
Conventional (or Clausewitzian) Warfare Strategy	Insurgents attack any COIN agent that is within sight. If more than one COIN agent is observed then the insurgent agent will randomly select one.

Martinez and Fitzpatrick found that the worst strategy for the insurgents (the "Red" side) is suicide attack, which inflicted casualties on the government ("Blue" side) but did not produce enough collateral damage in Blue's reaction to recruit more agents to the Red side. They were most interested in testing some of the ideas in U.S. counter-insurgency manuals for the Iraq war: "Sometimes, the more you protect your force, the less secure you may be; sometimes, the more force is used, the less effective it is; sometimes doing nothing is the best reaction." These are based on the theory that too much force risks killing civilians, "leading to a coercion influence response of a negative nature, literally driving civilians into the arms of the insurgents" (Table 3.6).

Table 3.6 - Blue's use of force and average number of deaths (Martinez and Fitzpatrick, 2011)

Blue's Use of Force	Average Number of Civilian Deaths	Average Number of Red Deaths*	Average Number of Blue Deaths
0%	7.91	42.05	2102.84
25%	68.19	100.57	989.68
75%	99.09	129.92	672.56
100%	107.20	137.05	611.03

However, Martinez and Fitzpatrick noted that "the current parameterization involves too high a rate of engagement and killing" in the model compared to reality for it to be "a quantitatively accurate predictor." They lamented the complexities in agent-based modeling of insurgency, writing that "parameter estimation is a very difficult issue" in insurgency models compared to other applications, which "is fraught with many practical problems of parameterization and data analysis" (p. 61).

The model used in this project (Sink and Travis, 2019) initially began as an expansion of the Rebellion model (Wilensky, 2004) in the NetLogo model's library (Wilensky, 2009). The context is thus set for an agent-based model of guerrilla warfare, this one focusing not on the causes or explanations for civil violence or war, but rather simulating the prosecution of it, and comparing and contrasting it to Fourth/Fifth Generation war.

Chapter 4 – Method

Unlike the natural sciences and even some social sciences such as psychology, the field of International Security Studies presents unique challenges for the researcher with respect to experiments. Observational studies, which proliferated with the advent of desktop computing, can provide only clues to causation. Experiments where variables can be controlled and studied are virtually impossible. In the early days of the systematic study of international politics and war, theory was almost entirely based on subjective historical analyses. Although the authors were often experienced practitioners, they were not necessarily trained scientists (Bull, 1966). By the mid-twentieth century, more general theories of international politics began to appear. Yet, most still suffered from lack of scientific rigor, although some researchers attempted to tease out the crucial variables using statistical methods available at the time (Braumoeller, 2016).

With the advent of inexpensive digital processing tools along with very serious efforts to organize and categorize historical conflicts into more useful databases, the 1980s and 1990s saw an explosion of observational studies (Sprinz, 2004). By the end of the first decade of the 21st century, powerful statistical analysis packages and better, more refined data were available to practically anyone (McNabb, 2010).

However, the inability to experiment continues to inhibit efforts to advance theory. The nearest analog we have to experimental methods are wargaming, modeling, and simulation. Meanwhile, while categorization of historical events helps in the quest for verification, most observable conflicts are characterized by complex interactions of variables that are endogenous, conditional, or perhaps improperly defined or selected. Errors due to inappropriate specification can accumulate and distort results to the point of uselessness. Fortunately, computational tools that can help in the quest for better theories are increasingly available.

We have seen this evolution in the other sciences. Engineering was almost exclusively an analytical exercise, using such abstractions as frictionless springs and perfectly elastic billiard balls in order to make the required differential equations solvable. At least, that was the case until numerical methods became much more practical and computationally feasible, and thus more attractive (and the solutions more accurate) with the introduction of inexpensive computing. The field of Economics has evolved from relying on gross simplifications such as the perfectly rational buyer with transitive preferences to more realistic behavioral modeling. At this point in the development of conflict studies, modeling, gaming, and simulation offer the promise of better insights leading to more accurate specifications.

Numerous computational methods exist for simulated various theories of international and civil conflict. Social network modeling, neural networks, system dynamics modeling, classic role-based wargaming with computational assistance, agent-based models, and formal mathematical modeling can all be useful in simulate real-world dynamics of conflict in international relations and drawing valid conclusions. Several different types of models were considered for this project. Wargaming was eliminated at the outset from a practical standpoint, because these normally require human participants to make the decisions prior to each “move” in the computational model. Network models can be used to simulate connections like those, for example, between rebels and their supporters, or the spreading of propaganda. But these tend to lack the topographic component that is vital to understanding how different physical environments contribute to the results of the simulation. Systems Dynamics models are highly flexible. The concepts of stocks and flows are especially useful in examining the logistical aspects of warfare, such as how resources are obtained, consumed, and allocated. On the other hand, agent-based models (ABMs) are particularly suited to interactions between organizations or individuals (the "agents") and to interactions of agents with the environment. In this project, the research was focused on how Fourth Generation tactics could potentially generate different behavior, and in turn, create different outcomes, all within the context of the geographic and topographic constraints normally present in insurgent warfare. Therefore, and ABM approach was selected.

Agent-Based Models (ABMs)

In agent-based modeling, micro-behavior is used as the motivator and producer of macro-behavior. Thus, dynamics of conflict are seen as arising from the interactions of agents with each other and the environment (Gilbert, 2008). An agent can be an individual, a nation-state, a cabinet, an interest group, a transnational group, or a host of other actors on the international scene. Moreover, the environment can be modeled to reproduce the salient features and constraints of the system. This is especially advantages in simulating warfare, which occurs in a geographic space, and where measures of merit almost always include territory gained and held. Emergent behavior can then be studied to determine how "individual components interact with and respond to each other and their environment" (Railsback and Grimm, 2012).

Method Overview

For this study, two related but different ABMs were developed for comparison. One model simulates 20th century style insurgency, and is called Classic Guerrilla Warfare, or "CGW."

The other model adds features of Fourth and irregular Fifth Generation Warfare and is called here "4/5GW." Both models pit organized insurgents against a state entity. Population agents are either pro-rebel, pro-government, or indifferent. One of the primary objectives of the rebel forces is to convert indifferent population agents to pro-rebel agents, and pro-government agents to indifferent agents. Forces are programmed with the rules that underlie military attack decisions, primarily the "3-1 rule" (attacks are possible if offensive forces outnumber defensive forces by better than a 3-1 ratio). The guerrillas are programed with rules that mirror guerrilla tactics.

The two models are then run under comparable terrain and initial conditions, and compared in several aspects:

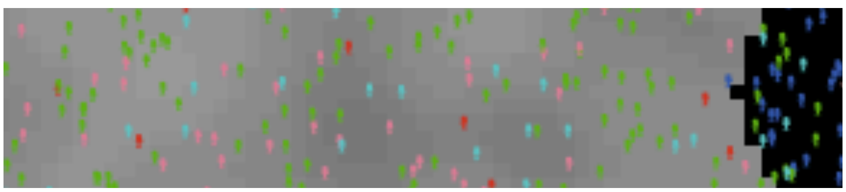
First, are there differences in the operational outcome of the two simulations? Specifically,

- Does 4/5GW confer advantage to one side or the other compared to CGW?
- Does 4/5GW shorten or lengthen time to victory in protracted war?
- Does 4/5GW change the amount of territory changing hands over comparable time periods (10 years in this study)?
- Does 4/5GW increase or decrease the rate of change of popular support for the government?

Two primary outputs (dependent variables) are envisioned for determining victory conditions for either side. The first is the relative military strength of each side. The second is the territory occupied. The aim is to infer from the simulations whether there are significant differences between the two styles of warfare to determine if 4/5GW is qualitatively distinct from CGW. If not, is 4/5GW simply "Mao with smart phones and internet?"

Model Description

Combatants and non-combatants are modeled by agents. The simulation incorporates some conventions from the field of wargaming, depicting the government forces as “Blue,” the insurgents as “Red,” and neutral non-combatants as “Green.” Some non-combatants actively support government forces and are depicted as either “Pink” (supporting the insurgents) or “Cyan” (supporting the government) (Figure 4.1). As in most ABMs, emergent behavior is produced by the agents interacting with each other and with the environment. In the initial condition of the models, Reds begin in the countryside, Blues begin in the cities, and Greens, Pinks, and Cyans are interspersed throughout the simulation space.



4.1 - Red, Pink, Green, Cyan, and Blue Agents

The environment for the agents to conduct conflict is characterized by terrain in a 100 by 100 (10,000-patch) operating space (Figure 4.2, below). Urban areas are depicted as black circles of random size with pink stars in their centers and are connected by roads, also shown in black. Terrain can be varied by degrees of roughness (Figure 4.3). Rough terrain has been identified in some studies as a facilitating factor for insurgency (Fearon and Laitin, 2003) (Tollefsen & Buhaug, 2015) although other studies have argued that the effect is indirect, operating mainly through state capacity (Hendrix, 2011) (Koren & Sarbahi 2018).

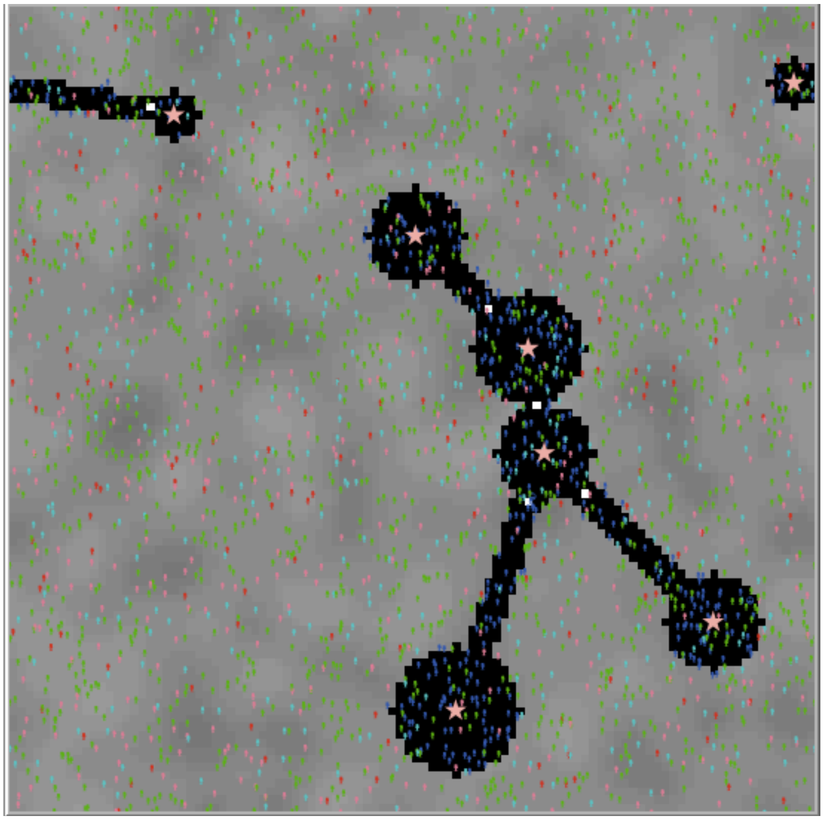


Figure 4.2 – Game Space

Open terrain allows faster movement, but offers less security, while rough terrain is more secure but movement for all agents is slower. Urban terrain is also difficult to move in. Cities (black) are connected by roads (also black) that offer faster mobility than countryside, but less security.

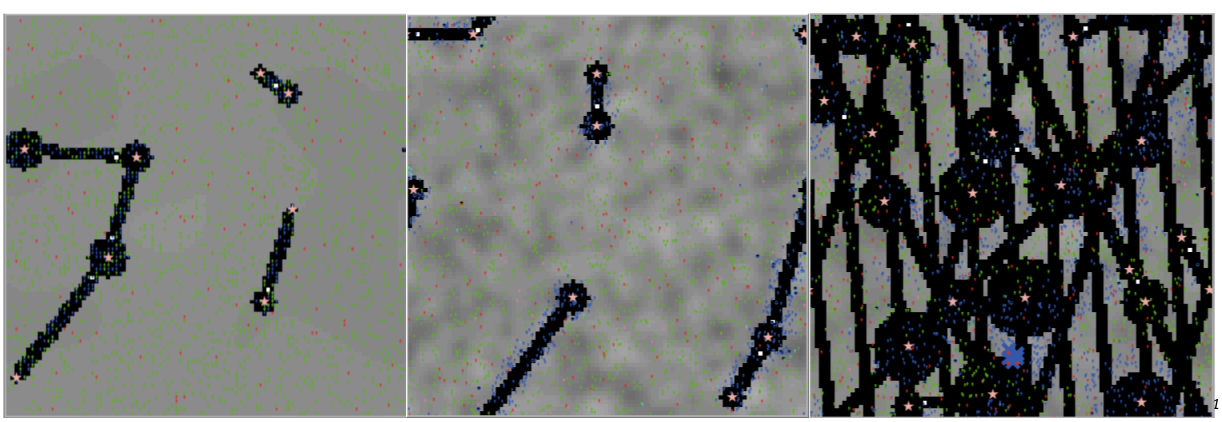


Figure 4.3 – Rural Smooth, Rural Rough, and Urban Terrain

Both models are based on an irregular warfare, a strategy of weak against strong. However, in the 4/5GW simulation, several differences noted by the authors of generational warfare literature have been incorporated. Communication is hastened, intelligence vision radius is greater, and certain tactics are enabled, specifically suicide bombs, near-instantaneous propaganda effects (internet dissemination), and rapid blue reinforcements (paratroopers or third-party participants). Specifically,

- Communications range (primarily used for movement decisions) is substantially increased in the 4/5GW model, to simulate 21st century communications over internet and mobile phone.
- Next, communications fidelity is increased in the 4/5GW model, simulating the improved intelligence accuracy inherent with timeliness of communications.

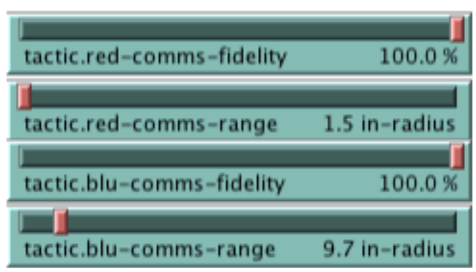


Figure 4.1 – Communications Selections

- Third, propaganda impact is increased in the 4/5GW model to simulate enhanced dissemination over social media compared to 20th century broadcast technologies (radio, film, and television).

Figure 4.2 – Propaganda Selections

- Fourth, Blue capability is enhanced with more rapid reinforcements, simulating enhanced mobility and more precise air support (which also leads to less Blue-caused collateral damage). In both models, the “spawn” rate can be adjusted, simulating the introduction of third-country Blue forces that support the government.

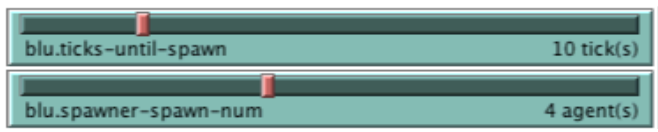


Figure 4.3 – Blue Spawn Function

- Fifth, the effect of the unemployment rate is included to simulate social conditions.

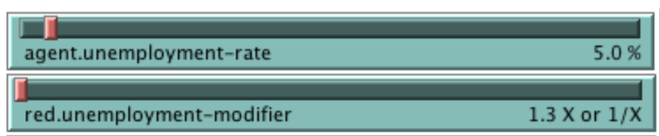


Figure 4.4 – Unemployment Selections

- Finally, red terrorist tactics are simulated with the addition of suicide bombs.

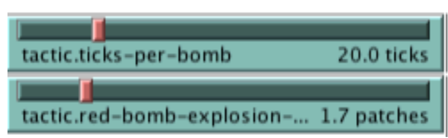


Figure 4.5– Suicide Bomb Selections

<u>Agent attributes</u>

The primary agents are the combatants, with some population (Pinks and Cyans) as supporting agents. Combatant agents are rebel forces and government forces (reds and blues).

1. When the occupying forces advance against the guerrillas to attack, the guerrillas withdraw and disperse.

2. Enemy forces will halt their advance unless a suitable target is identified. At this point the guerrilla agents are assumed to conduct harassing actions including sniping, sabotage, and hit-and-run tactics with weapons such as anti-tank rockets and mortar fire.
3. When defending forces are weaker (the classic military formulation is when a three-to-one advantage exists), the guerrilla agents attack (six-to-one in urban terrain). The probability for victory is set by the red.kill-probability and blu.kill-probability variables.
4. If a combatant is forced to retreat, the other force pursues them in order to destroy them.

Environmental Attributes

The terrain, in combination with military unit size, will dictate the speed of movement. Rough, urban or forested terrain will impede movement of large units, while only minimally impeding the movement and facilitating concealment of small units. Terrain types such as forest and urban areas can also offer concealment.

Concealment until the time comes to attack is a primary goal of the guerrilla. Guerrillas remain dispersed and concealed to gather intelligence, recruit supporters, and wait for opportunities to attack and destroy small or isolated enemy units. Concealment is envisioned to be a function of unit size, terrain, and communications activity level.

Communications capability, generally modeled as 20th century (radio and television) or 21st century (radio, television, internet, and personal camera and video-enabled mobile phones) will dictate the speed and quality of communications, which in turn will impact the speed of reaction. Guerrilla unit will mass to attack smaller government units, while government units will organize to provide security to the population and mount "search and destroy" attacks against the guerrilla units.

Communications capability facilitates the speed of reaction. For government forces with a high level of technological capability, the insurgents' plans and movements are more accurately predicted, increasing the likelihood of a successful counter for the government. Likewise, improved quality and dispersion of communications among rebel supporters are likely to increase the impact of insurgent anti-government propaganda, which can lead to both increased popular support for the rebels and decreasing support for the government.

Quality of intelligence impacts the success of the opposing forces. When popular support is high for a side, that side receives better intelligence. Likewise, when popular support decreases, quality of intelligence decreases as well. Quality of intelligence (modelled as communications fidelity) is different between CGW and 4/5GW, although this may be controversial. Some critics have argued that overreliance on electronic means of intelligence gathering has actually decreased the quality of intelligence (Margolis, 2013). They point to the fact that American forces in Iraq were stymied until the "2007 Sunni Awakening" released a flood of high-quality, "actionable intelligence" to the American forces (Koloski, 2009).

A summary of common features of the models are presented in the table below.

Table 4.1 – Summary of Environmental Effects

- Intelligence provides forces with knowledge of enemy size, strength, and location
    - Quality of information ranges from poor to perfect
    - Quality of information improves with popular support (more numerous intelligence-gatherers.
- Communications disseminates intelligence to guerrillas and government units.
    - Communications efficiency is variable (communication range)

- Mass communications such as social media and camera/video cell-phones can enhance the effectiveness of strategic messaging (propaganda impact and duration variables).
- Movement of units are constrained by terrain type and cover
    - Urban, rough terrain (simulating mountains or forest), plains and the presence of road networks are modelled
- Concealment (cover) is a function of faction (red or blue) and terrain
    - Concealed units are more difficult to target and attack
    - Massing forces reduces concealment and increase vulnerability.

Detailed Description of the Models.

The Overview, Design Concepts and Details plus Human Decision-making (ODD+D) protocol describes ABMs "in a standardized way, with an emphasis on human decisions and which includes the empirical and theoretical foundations for the choice of decision model." (Müller, et al, 2013). This structure has been adopted below to describe the computational models used for this research project. Figure 4.9, below, is a diagram illustrating the ODD+D, emphasizing the addition of decision-making and theoretical and empirical background "to encourage model designs and model assumptions that are more closely related to theory."

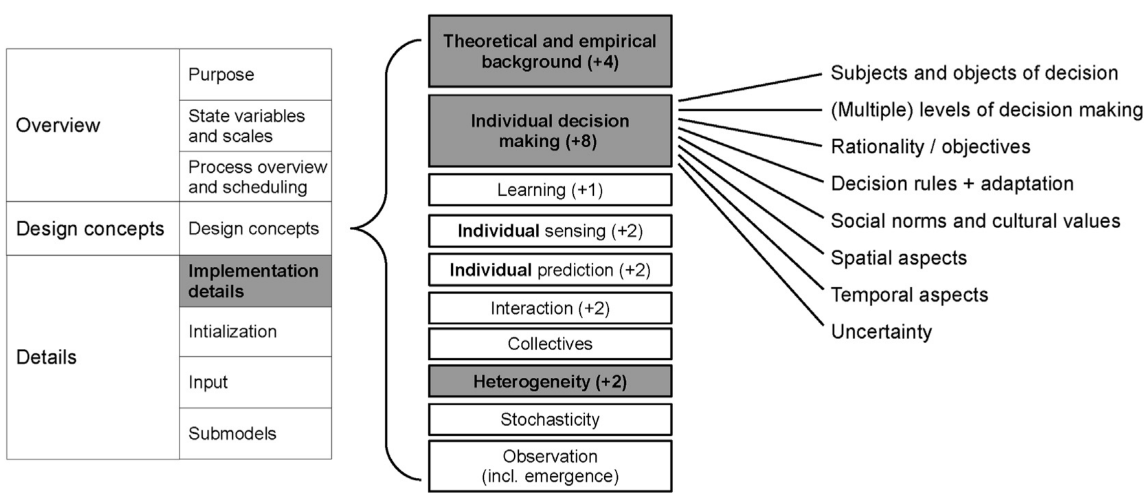


Figure 4.6 – ODD + D Framework for Documenting Agent-Based Models (Müller, et al, 2013)

Each element of the ODD + D framework from (Muller, et al, 2013) is quoted below in italics, and a detailed description of the element follows.

I.i.a What is the purpose of the study? The purpose of this study is to examine differences between so-called Fourth/Fifth Generation Warfare and theories of guerrilla warfare expounded through the end of the 20th century (what I have named here as “Classic Guerrilla Warfare”). The aim is to gain qualitative and quantitative insights into the differences between the two irregular warfare paradigms, and also to add academic rigor to the discussion of so-called generational theory by military authors. In order to support these objectives, two agent-based models are compared—one modeling guerrilla warfare as expounded by Mao and Ho in the mid- to late 20th century, and the other adding information-age advantages of near-instantaneous communications, mass-effects tactics such as suicide bombings, rapid mobility for government forces and other features of modern warfare.

I.i.b For whom is the model designed? The model is designed primarily for researchers who wish to study generational warfare theory using computational modeling, as well as students of irregular conflict or insurgencies. It is also meant to provide a platform for military authors and wargamers who wish to explore preventative measures for 4/5GW, by illuminating differences between well-understood models of insurgency and irregular warfare based on insurgent tactics of weakness against strength, or of an indigenous force against a central government alone or operating with support from third parties.

I.ii.a What kinds of entities are in the model? The model's features align with some conventions of the wargaming discipline. Both models consist of agents representing an indigenous insurgent force (red-colored agents, or "Reds") in armed conflict with a government military/police force (blue agents, or "Blues"). The warring agents operate within a population of unaffiliated non-combatant agents ("Greens"), who can be recruited to either faction as either supporters of the combatant Reds or Blues, providing only intelligence and logistics, or as active combatants. The recruitment module is similar in both the CGW and 4/5GW versions and is based on supporter agents that are color-coded as Pink (supporting the Reds) or Cyan (supporting the Blues). Greens cannot be recruited directly to either red or blue without at least one turn of recruitment to Pink or Cyan, respectively.

The environment for the agents to conduct conflict is characterized by differing terrain in a 100 by 100 (10,000-patch) operating space (Figure 4.10, below). Terrain can be varied by degrees of roughness. Rough terrain has been identified in some studies as a facilitating factor for insurgency (Fearon and Laitin, 2003) (Tollefsen & Buhaug, 2015), although other studies have argued that the effect is indirect, operating mainly through state capacity (Hendrix, 2011) (Koren & Sarbahi 2018).

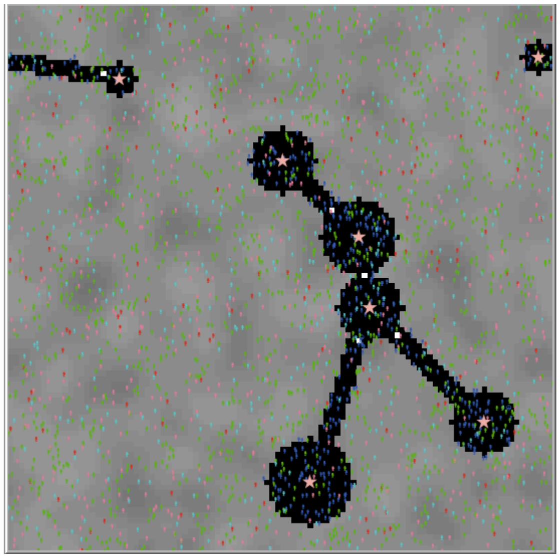


Figure 4.7 – Game Space

Open terrain allows faster movement, but offers less cover, while rough terrain is more secure but movement for all agents is slower (Table 4.2). Urban terrain is more difficult to move in. Cities (black) are connected by roads (also black) that offer faster mobility than countryside, but less cover (Table 4.3). In the 4/5GW version of the model, communication is hastened, intelligence vision radius is greater, and certain tactics are enabled, specifically suicide bombs, near-instantaneous propaganda effects (internet dissemination), and rapid blue reinforcements (paratroopers or third-party participants).

Table 4.2 – Movement Factors

	Movement (5 = best, 1 = worst)				
	Mountains	Hills/Forest	Plains	Roads*	Cities
Red	2	3	3	3/5	2
Blue	1	2	4	5	2
Green/C/P	2	3	4	5	3

*We assume red moves under cover next to the road, not on the road (movement = 3), unless in pursuit of retreating blue (movement = 5)

Red moves faster than blue in mountains and hills, but must move slower when in cities.

Blue moves quickly on roads and plains, but must slow down when approaching danger.

Everyone is slowed by rough terrain, but red is slowed less, because this is where they "live."

Table 4.3 – Cover Factors

	Cover (5 = best, 1 = worst)				
	Mountains	Hills/Forest	Plains	Roads*	Cities
Red	5	3	2	2	4
Blue	4	2	1	1	4

Civilians (Green, Pink, Cyan) move without consideration of cover.

I.ii.b By what attributes (i.e. state variables and parameters) are these entities characterized? Agents are characterized by their affiliation (neutral, insurgent, insurgent sympathizer, soldier, government sympathizer). They also have a recruitment factor that tells how likely they are to change affiliations. Active combatants, red and blue, have a probability of kill that operates during an engagement with the enemy. Terrain is characterized by a movement factor and cover factor (as shown above), which is different for the respective agents, blue or red, occupying it.

I.ii.c What are the exogenous factors/drivers of the model? The exogenous factors driving the model are the initial populations and density of Greens, Blues, Reds, Pinks, and Cyans, along with the percentage and roughness of the various terrain types. The models are also driven to some extent by the initial kill probabilities assigned to the various forces, the speed and range of communications, intelligence vision radius (limited in the CGW model but simulating all-source intelligence, including operatives, overhead—satellites and drones, and fusion centers in the 4/5GW model), and the enabling of 4/5GW tactics, i.e. blue airdrop reinforcements, and suicide bombs.

I.ii.d If applicable, how is space included in the model? Space is included in the model in the form of the 100 by 100 terrain matrix. Notional space, such as countries of third parties, oceans, and water obstacles are not modeled to the extent that impediments to movement are included in the rural terrain modeling approaches.

I.ii.e What are the temporal and spatial resolutions and extents of the model? Space is bounded by 10,000 patches, and time is allowed to progress for 260 weeks (10 years) to approximate a sufficient block of time for the variables to play out in an irregular warfare scenario.

I.iii.a What entity does what, and in what order? Agents move based on agent affiliation (combatant or non-combatant) and terrain type. First, territory occupied by the various factions is calculated. Next, government legitimacy is updated based on the previous turn's results. Then, each agent's faction is updated based on the recruitment subroutine. Non-combatants move randomly. If combatant (Red or Blue) agents are on alert based on proximity and movement of enemy forces, they either move to contact with the enemy, or they retreat, based on their side's intelligence of their expected advantage (the anticipated force ratios favoring their side). If an agent is not on alert, the agent will attempt to recruit non-combatants (Pinks and Greens if the recruiting agent is Red, or Cyans and Greens if the agent is Blue) through bribing (receiving a reward) or coercing the non-combatant—this is in addition the propinquity factor (proximity to one or another faction) and the propensity assigned at birth, as described above. The individual agents then update their own self-identity (Red, Blue, Pink, Cyan, or Green) and proceed to move. At this point, tactics are enabled, either CGW or 5GW.

II.i.a Which general concepts, theories or hypotheses are underlying the model's design at the system level or at the level(s) of the submodel(s) (apart from the decision model)? What is the link to complexity and the purpose of the model? General concepts for the two models are taken from irregular warfare theory, the most prominent authors of which are Mao (1989) and Ho (Giap, 1971, 1978). 4/5GW Warfare theory is championed mainly by Lind (1989), Hammes (2005, 2006, 2007), and Reed (2008). Recruitment is based on four factors (Martinez and Fitzpatrick, 2011): propensity to change affiliation is a function of propensity to lean red or blue, which is randomly assigned at birth; "propinquity," which is the influence of the affiliation of neighboring agents; the effects of receiving a reward; and the effects of coercion.

A third subroutine in the model includes the effects of government legitimacy on the conflict. As Blues are defeated and collateral damage occurs, the government legitimacy decreases, which in turn facilitates the recruitment of Greens to Pinks, and of Pinks to Reds. Conversely, red losses in battles and red-caused collateral damage increase government legitimacy, improving recruitment prospects for the government of Greens to Cyans and Cyans to Blues. Finally, the unemployment rate impacts both government legitimacy and ease of recruitment, as a higher unemployment rate lowers legitimacy and makes recruitment to the insurgency more likely (Fearon and Laitin, 2003). Although the model incorporates this assumption, it is disputed by Berman, et al (2011).

II.i.b On what assumptions is/are the agents' decision model(s) based? The decision model for the agents is based on force ratio and results of combat—forces must anticipate at least a 3-to-1 local advantage in rural terrain, or a 6-to-1 advantage in urban terrain or on roads in order to move to contact with the enemy (Clausewitz, 1976) (U.S. Army, 1990). If an engagement is lost, agents retreat and either disperse (Reds) or attempt to regroup, reinforce and concentrate (Blues).

II.i.c Why is/are certain decision model(s) chosen? The dispersion function on retreat for red is based on the insurgency imperative to avoid creating a footprint or target for the enemy to easily find and pursue. The decision model is based on Mao's description of guerrilla tactics (see Chapter 2).

II.i.d If the model/submodel (e.g. the decision model) is based on empirical data, where do the data come from? Several of the modeling elements are built from empirical data, based on the results of previous studies. Initial values for Red and Blue force size as a percentage of population are based on averages. The initial value of 89% for government legitimacy is based on an agent-based legitimacy feedback model for civil unrest developed by Lemos, Lopes, and Coelho (2013), who explored ranges of initial government legitimacy value of 0.85 to 0.89. Initial population estimates were drawn from experimentation and then adjusted during the quasi-global sensitivity analysis to produce rough equilibria. Kill probabilities for red and blue were likewise set to 50% in the CGW model, and to 50% and 70%, respectively, in the 4/5GW model based on increased lethality and target discrimination of 21st century weapons, and then adjusted for equilibria based on the sensitivity analyses.

II.i.e At which level of aggregation were the data available? The data are available as both individual inputs and outputs. These include values of independent and dependent variables, the settings of various switches, and constants based on quasi-global sensitivity analyses to produce functioning programs, and are computed for each two-week period ("bi-week"). Aggregate results were also complied by allowing the different scenarios to run to completion based on a notional length for protracted conflict, (maximum of 10 years/260 bi-weeks).

II.ii.a What are the subjects and objects of the decision-making? On which level of aggregation is decision-making modelled? Are multiple levels of decision making included? Agents make decisions (attack, retreat, recruit, etc.) relative to the other agents and terrain, particular city terrain where a six-to-one advantage is necessary. Agents move individually based on intelligence radius and on the characteristics of the terrain occupied (movement speed and cover from detection, as constrained by the terrain).

II.ii.b What is the basic rationality behind agent decision-making in the model? Do agents pursue an explicit objective or have other success criteria? Decision-making is at the agent level, with each agent representing either a combatant unit or a cohort of neutral or faction-supporting civilians. Red and Blue agents attempt to recruit neutrals to become supporters and attempt to recruit supporters to become active combatants. Combatants attempt to battle when they expect to win.

Agents' explicit objective is to engage and defeat the enemy (if red or blue), and to recruit non-combatants (green, pink, and cyan). Implicit or emergent goals are to occupy territory, gain support from the population at large, reduce or increase government legitimacy to favor their respective sides, and in blue's case, to specifically avoid collateral damage. Success criteria is measured to occupy more than 10 percent of the enemy's territory with a force 10 percent larger than the enemy's.

II.ii.c How do agents make their decisions? Agent decision making is illustrated below in the combat submodel flowchart (Figure 4.11)

II.ii.d Do the agents adapt their behavior to changing endogenous and exogenous state variables? And if yes, how? Agent behavior does not vary with changes in endogenous and exogenous state variables, although numbers of agents will change above the initial values in the 4/5GW model, in that Blue will receive overseas reinforcements and enhanced mobility.

II.ii.e Do social norms or cultural values play a role in the decision-making process? Decrease in government legitimacy and collateral damage do not play a role in individual decision-making. Collective behavior changes in that larger forces are more likely to move to contact.

II.ii.f Do spatial aspects play a role in the decision process? Cover is the spatial aspect that impacts decision making process. Agents will not leave cover to attack unless they expect tactical victory.

II.ii.g Do temporal aspects play a role in the decision process? Temporal aspects play a role in the decision-making process insofar that agent decisions are modified based on intelligence vision radius (which simulates speed of communications). However, the instantaneous values of the relevant variables, not the rate of change, determine the agent's decisions. The recruitment rate changes with time based on the four recruitment factors (propensity, propinquity, rewards, and coercion) and with government legitimacy, so an agent's affiliation may change with time, which will in turn affect decision making. The overall nr of enemy and collateral kills change with time based on the combat submodel, so this will affect the decisions to attack through the local offense-defense ratio calculation.

II.ii.h To which extent and how is uncertainty included in the agents' decision rules? Uncertainty is included in the agents' behavior in the aspect of kill probabilities for red and blue, and in the uncertainty inherent in the recruitment process (based on the four factors of propensity, propinquity, reward, and coercion).

II.iii.a Is individual learning included in the decision process? How do individuals change their decision rules over time as consequence of their experience? Individual learning is not implemented in the models. The agents consistently apply the tactics of irregular warfare and do not change their decision rules as a consequence of experience over time.

II.iii.b Is collective learning implemented in the model? Collective learning is not implemented in the model.

II.iv.a What endogenous and exogenous state variables are individuals assumed to sense and consider in their decisions? Is the sensing process erroneous? Combatant agents possess the exogenous state variables of communications range, communications fidelity, detection range, and attack range. Communication range is the distance at which agents can communicate intelligence information to each other. Detection range is the distance at which agents can detect the enemy and force size. Attack range is the range at which the agent can move to engage the enemy if favored by force ratios (normally 3-1 but 6-1 in urban terrain). In the CGW model, communication and detection ranges are shorter than in the 4/5GW version, simulating improved communications and intelligence.

II.iv.b What state variables of which other individuals can an individual perceive? Is the sensing process erroneous? Combatant agents can count enemies within the detect range and calculate victory probabilities, but they cannot perceive the state variables of their enemy (e.g., victory confidence). Combatant agents can also determine terrain within the communications range and incorporate terrain type into victory calculations.

II.iv.c What is the spatial scale of sensing? Spatial scale of sensing is 1.5 patches in the CGW model. It is increased to 11 in the 4/5GW version of the model.

II.iv.d Are the mechanisms by which agents obtain information modelled explicitly, or are individuals simply assumed to know these variables? The mechanism of gathering information is modeled implicitly, not explicitly, in the models through the detection and communications ranges of the combatants and supporters. Rather than collecting information from supporters as in real life, agents gather intelligence through the variables of communications and detection ranges and communications fidelity.

II.iv.e Are the costs for cognition and the costs for gathering information explicitly included in the model? Costs of cognition and information gathering are not explicitly included in the model, but rather, implicitly, in the costs of recruiting supporters (reward portion).

II.v.a Which data do the agents use to predict future conditions? Combatant agents use force ratios within detect range to predict victory conditions (victory confidence variable) and thus make attack decisions.

II.v.b What internal models are agents assumed to use to estimate future conditions or consequences of their decisions? The victory confidence variable, used to predict future conditions and decide whether or not to attack an enemy with range, determines attack decisions in both models. If there is no enemy within range, combatants carry on with normal activities or reinforce allies, if required. If enemy is within range and victory confidence calculates a tactical advantage (force ratios are favorable), an attack decision is generated. If , on the other hand, the force ratio is unfavorable, the calculating combatant retreats and carries on.

II.v.c Might agents be erroneous in the prediction process, and how is it implemented? Agents will sometimes be erroneous in the prediction process, depending on the kill probability state variable. For example, agents with a kill probability of 50% will have an erroneous victory confidence level about half the time they decide to attack.

II.vi.a Are interactions among agents and entities assumed as direct or indirect? Interactions among the agents are assumed to be direct. As previously described, combatant agents are constantly recruiting supporters/sympathizers to their faction. Agents can reward or coerce other agents to join their side.

II.vi.b On what do the interactions depend? The interactions depend on the faction of the agent and on the propensity, propinquity, rewards, and coercion that the agent experiences.

II.vi.c If the interactions involve communication, how are such communications represented? Battle is represented by large crosses showing where battles are taking place. Recruitment is represented by a change of color in the agent. Communication is implicit only, in the communications range and fidelity, detect range, and attack ranges, and is inherent in the knowledge of enemy positions available to the combatants.

II.vi.d If a coordination network exists, how does it affect the agent behaviour? Is the structure of the network imposed or emergent? Combatant agents coordinate with supporters (e.g., Reds with Pinks) via the allies variable. Allies assist own-side combatants in determining the enemy force dispositions. Behavior is affected in that victory confidence is varied, thereby impacting attack decisions. Also, as agents are eliminated through combat and collateral deaths, force ratios are varied globally as movement impacts local force ratios. Although the structure of the model for attack and retreat decisions is imposed, coordination itself is emergent, because it depends on the recruitment model. The number of agents in each faction is updated every turn, which translates into constantly varying local victory condition calculations. Moreover, in the 4/5GW version model, blue reinforcements from a 3rd party are received, thus changing both the total number of agents and faction ratios.

II.vii.a Do the individuals form or belong to aggregations that affect and are affected by the individuals? Are these aggregations imposed by the modeler or do they emerge during the simulation? Individuals form factions (allies and enemies) that affect and are affected by the individuals. Faction membership determines agent behavior toward allies and enemies. Although the initial faction size of Green, Red, and Blue agents are externally set, the factions of Allies and Enemies emerge as the simulation progresses and are a function of the recruitment submodel.

II.vii.b How are collectives represented? Collectives are represented as factions (Reds, Blues, Greens, Pinks, and Cyans). They are also represented as Allies (Reds and Pinks or Blues and Cyans) or Enemies (Reds and Blues).

II.viii.a Are the agents heterogeneous? If yes, which state variables and/or processes differ between the agents? Agents behave homogenously within each faction. However, each agent carries a specific state variable "L," which is their likelihood to convert factions on the next turn. As described above, L is dependent on four factors: propensity assigned at birth, propinquity (influence of the factions of surrounding agents), and reward and coercion history. L is unique for each agent in the sense that initial propensity is randomly generated, propinquity is dependent on the faction distributions in the surrounding spaces, and reward and coercion history depend on the agent's interaction experience for the last 10 turns. Thus, as the models progress, agents gain heterogeneous values of L.

II.viii.b Are the agents heterogeneous in their decision-making? If yes, which decision models or decision objects differ between the agents? Once an agent's faction is determined, agents are mostly homogeneous in their decision-making, although Reds and Blues differ in that Blues attempt to retreat to cities while Reds retreat to the countryside, their respective "bases."

II.ix.a What processes (including initialization) are modeled by assuming they are random or partly random? Various processes are modeled by assuming they are partially or fully random. Terrain is generated randomly, including city locations. However, terrain can be selected at various degrees of smoothness. Number of cities and city maximum and minimum radius are selectable, but once selected, the precise layout will be random. Generation of agents across the game space is partially random, with reds spawning in the countryside, Blues spawning in the cities, and Greens spawning anywhere. Propensity to join a faction is random, with a selectable mean and standard deviation. Outcomes of battle are determined stochastically after assigning a kill probability.

II.x.a What data are collected from the ABM for testing, understanding and analyzing it, and how and when are they collected? Data collected were the state variables of the model and the dependent variables of territory and percentage territory occupied by the respective forces, time to victory (if not stalemate condition by 260 weeks) and categorical victor (red or blue). NetLogo's built-in data extraction program, Behavior Space, was used to capture the data. Data was cleaned in Excel and then analyzed using Stata.

II.x.b What key results, outputs or characteristics of the model are emerging from the individuals? (Emergence) As the model progresses, the number and types of agents changes, as Greens are recruited to Pinks and Cyans, and Pinks and Cyans are recruited to Reds and Blues. Territory is occupied by Reds and Blues, and changes in the landscape emerge with time. Key outputs are territory occupied and force ratios between Red and Blue. When both territory and troops of one side are 10% higher than of their opponents, the victory condition is recorded. If neither side achieves victory, a stalemate condition is recorded.

III.i.a How has the model been implemented? The models were implemented in NetLogo, Version 6.1.1 (Wilensky, 1999).

III.i.b Is the model accessible, and if so where? The model is accessible at (Sink and Travis, 2019)

III.ii.a What is the initial state of the model world, i.e. at time t = 0 of a simulation run? The initial state of the model variables is shown in Table 4.4, below:

Table 4.4 - Common Initial Conditions for Model Runs

agent.enable-combat	*TRUE*	*grn.Bb.impact*	*4*
agent.enable-conversion-to-blu	*TRUE*	*grn.Bc.impact*	*4*
agent.enable-faction-conversion	*TRUE*	*grn.Bi.impact*	*4*
agent.unemployment-rate	*5*	*pnk.Bb.impact*	*1*
blu.attack-range	*1.8*	*pnk.Bc.impact*	*1*
blu.Bb.impact	*2*	*pnk.Bi.impact*	*1*
blu.Bc.impact	*1*	*pop.density*	*30*
blu.Bi.impact	*3*	*propensity.mean*	*2*
blu.density	*10*	*propensity.sd*	*2*
blu.detect-range	*3.5*	*red.attack-range*	*1.5*
blu.spawner-spawn-num	*2*	*red.Bb.impact*	*1*
blu.ticks-until-spawn	*10*	*red.Bc.impact*	*1*
cyn.Bb.impact	*2*	*red.Bi.impact*	*1*
cyn.Bc.impact	*1*	*red.density*	*5*
cyn.Bi.impact	*3.5*	*red.detect-range*	*3*
display.plot-x-range	*50*	*red.unemployment-modifier*	*2*
gov-legit-weight	*0.1*	*smoothing*	*4, 50, 100*
grn.Bb.impact	*4*	*stat.calculate-dynamic-gov-legit?*	*TRUE*
display.plot-x-range	*50*	*stat.initial-gov-legit*	*0.89*
gov-legit-weight	*0.1*	*tactic.lk-impact-decay-rate*	*0.9*

III.ii.b Is the initialization always the same, or is it allowed to vary among simulations? Initialization terrain parameters are varied to meet the conditions for the specific terrain scenarios being explored (see discussion below). However, within each terrain scenario initialization is the same for each pair of model runs for comparison (CGW and 4/5GW).

III.ii.c Are the initial values chosen arbitrarily or based on data? In determining the initialization, some data were chosen based on trial and error to achieve equilibrium conditions in the models with all three subroutines operating (combat, recruitment, and government legitimacy). Other initial values were chosen as specific independent variables, such as terrain type (rural rough, rural plains, and urban) in the quasi-global sensitivity analysis. Other variables such as percentage of insurgents, attack ratios, and victory probabilities were chosen based on reasonable values gleaned from literature on warfare.

III.iii.a Does the model use input from external sources such as data files or other models to represent processes that change over time? The models do not use inputs from external sources to represent processes that change over time.

III.iv.a What, in detail, are the submodels that represent the processes listed in 'Process overview and scheduling'? As described above, there are three submodels running simultaneously in the two main irregular warfare models, CGW and 4/5GW.

<u>The Combat Submodel</u>

The combat model looks for enemy agents within the attack range. The potential attacker looks for a 3 to 1 advantage in forces (6 to 1 in urban terrain). If this criterion is met, then combat occurs. A random number is then compared with the associated kill probabilities, and victory or defeat is assigned for that engagement. Next, collateral damage of potential victims is calculated. Any agents who are still alive following engagement then retreat. Figure 4.11, below, shows the combat submodel in flow chart form:

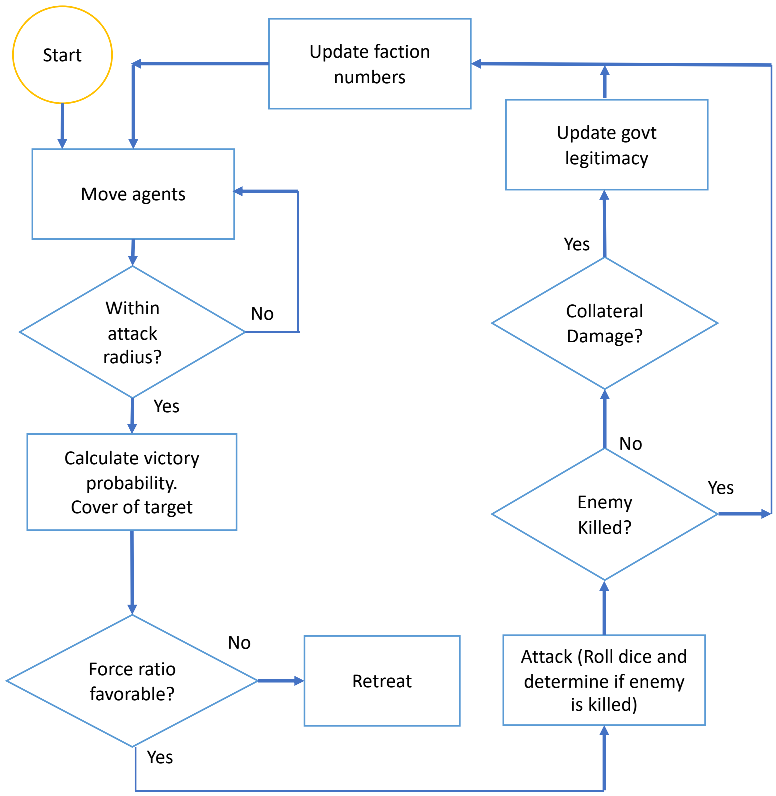


Figure 4.8 - Combat Submodel

The Recruitment Submodel

As described above, the recruitment model uses the state variable L to describe the likelihood of conversion to a different faction k:

$$L_k = \frac{e^{G_k + \beta_i (I_k) + \beta_b (B_k) + \beta_c (C_k)}}{1 + e^{G_k + \beta_i (I_k) + \beta_b (B_k) + \beta_c (C_k)}}$$

Where

L_k is a vector of five elements containing an agent's likelihood of joining the *kth* group (red, pink, green, cyan, or blue), depending on four factors, *G, I, B,* and *C*.

G_k is an agent's natural propensity to join *k* group, assigned randomly at birth.

I_k is the proportion of individuals who belong to each group *k* in the agent's physical neighborhood (propinquity).

The number B_k refers to the agent's expected rewards for belonging to *k* group

The number C_k refers to the amount of coercion that the agent has received from members of *k* group. This is defined as the proportion of times that one has been punished in the last ten turns with members of each *k* group.

The coefficients β_i , β_b , and β_c are the relative weights of propinquity, the reward impact, and the coercion impact, respectively, to normalize units.

(Martinez & Fitzpatrick, 2011)

The models report the internal states of the various factors of L for each faction (see Figure 4.9 below).

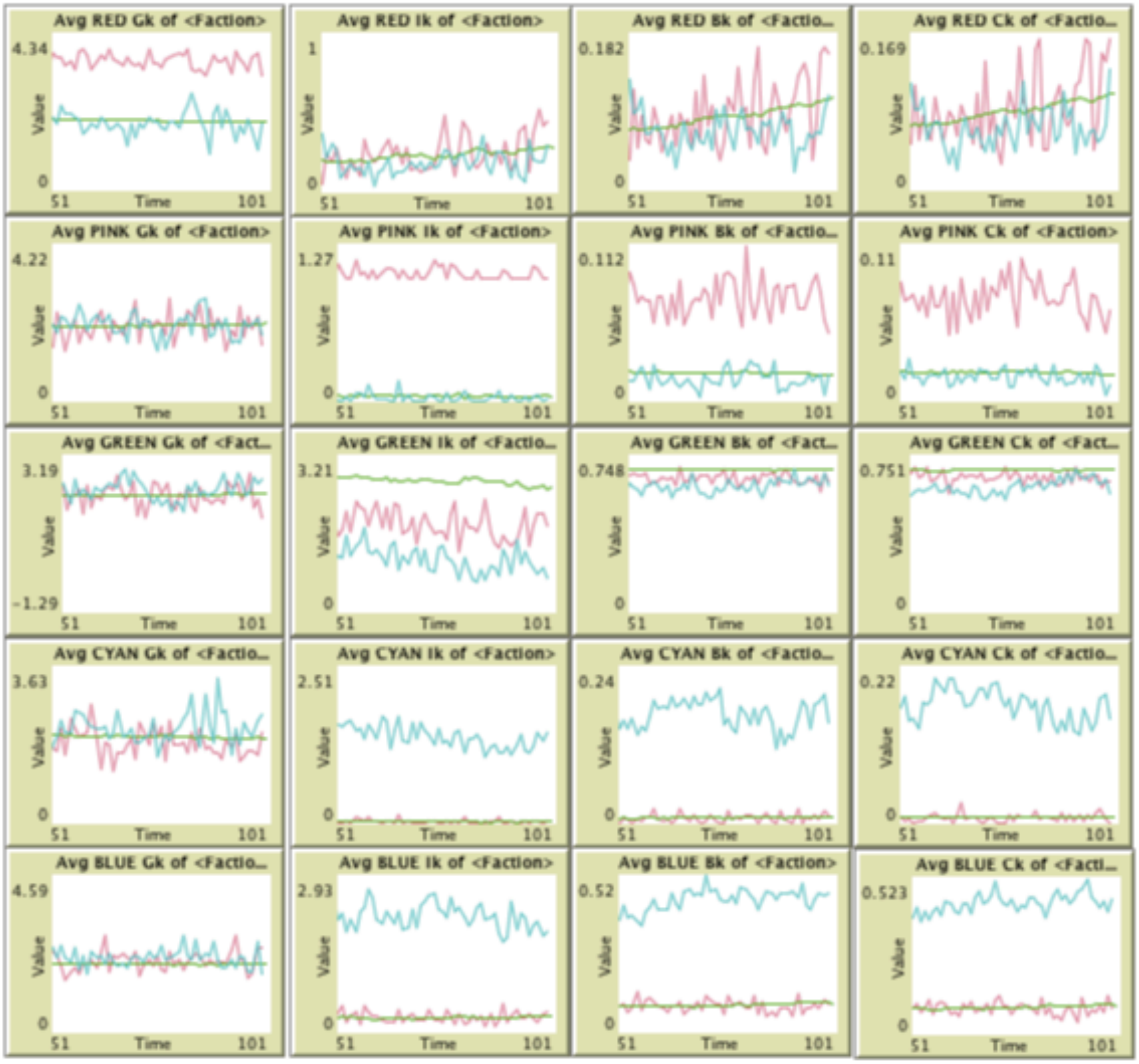


Figure 4.9 - Internal factors of recruitment for Each Faction

<u>The Government Legitimacy Submodel</u>

The legitimacy sub-models include the effects of the legitimacy of the government in increasing or decreasing the likelihood of recruitment to Red or Blue sides. The Legitimacy models are adapted from (Lemos, et al, 2015) which explores government legitimacy feedback in civil disobedience:

$$L^* = L_t - (N\text{arrests}_t / N\text{citizens}) - A_f \cdot (N\text{fights}_t / N\text{citizens})$$

$$\Delta L = \left(L^* - L_0\right) \cdot \exp\left(-\alpha \cdot \Delta t\right)$$

$$L_{t+1} = \max\left(0, \min\left(L_0 + \Delta L, 1\right)\right)$$

where L^* is the legitimacy score, L_0 is the initial government legitimacy, "$N\text{arrests}_t$ and $N\text{fights}_t$ are the number of arrests and recorded fights at time t, A_f is an 'audience factor' and α is a 'memory constant' that allows for slower or faster decay of the legitimacy drop due to arrests and fights in subsequent time cycles," and ΔL is the change in Legitimacy (Lemos, et al, 2015). Instead of arrests and fights, the models for this project uses number of battles and collateral deaths for the independent variables, respectively.

III.iv.b What are the model parameters, their dimensions and reference values?

The CGW and 4/5GW models each run three distinct terrain scenarios to simulate the general geographic conditions that distinguish insurgency warfare: rural terrain (open), rural terrain (rough), and urban terrain (Figure 4.10).

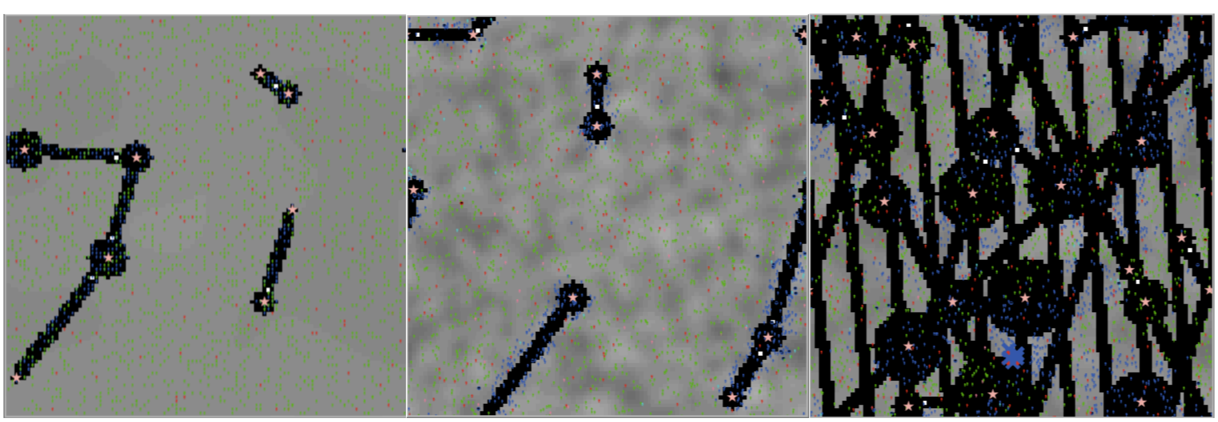


Figure 4.10 - Rural Smooth, Rough, Urban

The two models simulate the terrain by varying the "smoothness" parameter and reducing the radius and number of cities. Smooth patches simulate open terrain, rough patches simulate rough terrain, and numerous large cities represent an urban battlescape. Government forces spawn in the cities, while insurgents spawn in the countryside. Once the model is activated, the combat, recruitment, and government legitimacy sub-models run in the CGW and the 4/5GW main models. Thus, the two main models are compared across the three terrain scenarios (Table 4.5).

Table 4.5 - Terrain Scenario Input Parameters

	Rural Smooth	Rural Rough	Urban
Smoothness	100	4	50
Number of Cities	8	8	20
Max radius of cities	2	2	10
Min radius of cities	1	1	1

Each terrain scenario is run in the CGW model and the 4/5GW version. Some of the parameters in the 4/5GW model are varied to simulate the postulated differences between the two. Blue's kill probability and collateral damage probability are increased from 50% to 70% to simulate increased lethality of government forces with modern weapons. Communications range and fidelity is increased from 1.5 to 5 and from 50% to 95% for both Blue and Red in the 4/5GW scenario. Suicide bombs are introduced in the 4/5GW model. Propaganda effectiveness is increased. A list of the differences in the parameters between the two models is presented below (Table 4.).

Table 4.6 - Parameters of CGW and 4/5GW models

	CGW	4/5GW
tactic.blu-comms-fidelity	*50*	*95*
tactic.blu-comms-range	*1.5*	*5.0*
tactic.blu-propaganda-duration	*12*	*12*
tactic.red-propaganda-duration	*10*	*20*
tactic.red-bomb-explosion-radius	*N/A*	*1.5*
tactic.red-comms-fidelity	*70*	*95*
tactic.red-comms-range	*1.5*	*5.0*
tactic.ticks-per-bomb	*N/A*	*20*
tactic.blu-propaganda-lk-impact	*1.5*	*2.0*
tactic.red-propaganda-lk-impact	*1.5*	*2.0*
tactic.ticks-per-blu-propaganda	*0.5*	*2.0*
tactic.ticks-per-red-propaganda	*10*	*2.0*
red.kill-probability	*50*	*70*
red.collateral-kill-probability	*50*	*50*
blu.kill-probability	*50*	*90*
blu.collateral-kill-probability	*50*	*70*

III.iv.c How were the submodels designed or chosen, and how were they parameterized and then tested? The submodels were designed or chosen based on theory. The combat model is based on insurgency theory (Mao, 1989), and implements a weak force against a strong force for a protracted period of time in a war of attrition (Cioffi-Revilla and Rouleau, 2010). The recruitment model is based on Martinez and Fitzpatrick (2011), and the government legitimacy model is based on Lemos, et. al. (2015).

The combat submodel was parameterized using a Quasi-Global Sensitivity Analysis. The initial force ratios between red and blue were varied systematically and the resulting dependent variables, occupied territory and time to victory were analyzed. Analyzing another dimension, kill probabilities were varied for Red and Blue to verify that mid-range values centering on 50% produced results with more variation for analysis. Initial values of red and blue proportions that produced solutions that resulted in both red and blue victories and stalemates (between 7 and 12 percent difference between initial red and blue forces), along with kill probabilities of 40 – 70%, became the basis for the simulations.

The recruitment submodel was parameterized by experimentation. For propensity, an initial normal distribution of 2 with a standard deviation of 2 was found to produce a slow but detectable basis for recruitment. The values for β_i, β_b, and β_c were also arrived at through assumption and experimentation. The assumptions are that recruitment is a slow process and change in orientation will take time, and that all of the factors are equally weighted. Various combination of the β coefficients were run and a combination that produced slow and stable recruitment was selected.

The government legitimacy initial value was parameterized at 89% based on the recommendation of Lemos. "It was found that the case L_0 = 0.89 provided the richest and most interesting opportunities for further exploration, so we selected it for further study and consideration herein…L_0 = 0.89 is [also] very close to the limiting value for which rebellion peaks cannot occur" (Lemos, et al, 2015). However, dynamic legitimacy L was allowed to vary anywhere from 0 to 1.

This concludes the description of the method and model. The next section discusses the general congruence of the guerrilla warfare model with theory and historical record of insurgency.

Chapter 5 – Verification and Validation

This chapter examines the congruence of the models to historical civil war. First, three parameters—namely, initial force sizes, unemployment, and government legitimacy—were varied to provide dynamic variation in the model in addition to that from the three terrain scenarios (urban, rural rough and rural smooth). Initial force size ratio is used to calibrate the model to produce the most variation, since the force sizes and battle area are notional and abstract. The model test runs verified that the models functioned as designed (i.e., unemployment increases likelihood of Red victory, government legitimacy increases chance of Blue victory, collateral damage reduces support for the side causing it, etc. The model's sensitivity to the three parameters is illustrated with several examples.

Next, some examples of post-1946 civil war are presented and discussed, and the model's output is compared to actual cases of civil war contained in two databases, the Correlates of War (COW) Intra-State war database, and the COW Territorial Change database (Tir, et.al., 1998). The model is input with parameters approximating the conditions present in the conflict at the time of initiation, and then the simulation is run for the number of bi-weekly periods that the actual conflict lasted. The results of the simulation, in terms of final force ratios and the identity of the victor (with percentages of Red victories, Blue victories, or Stalemates in the model runs), are then compared to the historical data in COW. In most scenarios, the force ratios produced by the model are the same order of magnitude as in the historical data and the identity of the victor is correctly determined in the plurality of runs.

Finally, in order to obtain a macro view of the fidelity of the simulation, standardized values of red and blue kills are compared to the standardized combatant deaths of Sides A and B of internal civil wars as tabulated, and the standardized area of territory gained is compared to the standardized territory exchanged in civil conflicts, as reported in the COW records. The results show that the model is a reasonable proxy for modeling insurgency scenarios.

Verification and Sensitivity of Parameters

The parameters of the CGW model were adjusted in test runs during the development process to achieve both variability for analysis, as well as a results space where both red and blue victories were the outcome. The two models of warfare were run and compared across a period of 10 years, with each model turn ("tick") representing two weeks in real time. All three terrain scenarios—rural rough terrain, rural smooth terrain, and urban terrain—were tested. Three parameters in particular were the focus of adjusting the CGW model to produce variability in results across all three terrain sets: initial force ratios of red and blue forces, unemployment, and government legitimacy.

Initial force ratios had the largest impact on the results of the test runs. Too large an initial guerrilla population produced only red victories. Likewise, a large initial soldier population resulted in only blue victories. Moreover, historical data on initial force sizes is often unavailable for insurgencies. Therefore, in order to provide an output of the richest variance in war outcome, a sensitivity analysis was performed to determine the best initial force ratio.

The unemployment rate, used as a rough proxy for poverty, was varied primarily to model a dynamic effect on red recruitment. One would expect that as unemployment rises, red recruitment rates would improve due to generalized reduced opportunity for other employment. However, Cramer (2015) argues that there is not enough direct evidence to support this conclusion, mainly due to the unreliability of unemployment data (especially youth unemployment) in developing countries. Nevertheless, an effect was included in the models to provide additional variation beyond the terrain types.

Finally, government legitimacy was varied as an indicator of general dissatisfaction with the government. Again, one would expect that as government legitimacy decreased, red recruitment would improve, since citizens would be more likely persuaded to become supporters, then participants, in armed action against the government (Rotberg 2003) (Grimm and Merkel, 2008).

Blue-Red force ratios: As expected, the territory gained and time to victory were most sensitive to the initial force ratios. The effect of varying the red force ratio on red territory gained is shown in the graph below. As the initial number of guerrillas ("red_density") is increased, the amount of territory controlled after 10 years (the "red_cont" variable) is also increased (Figure 5.1).

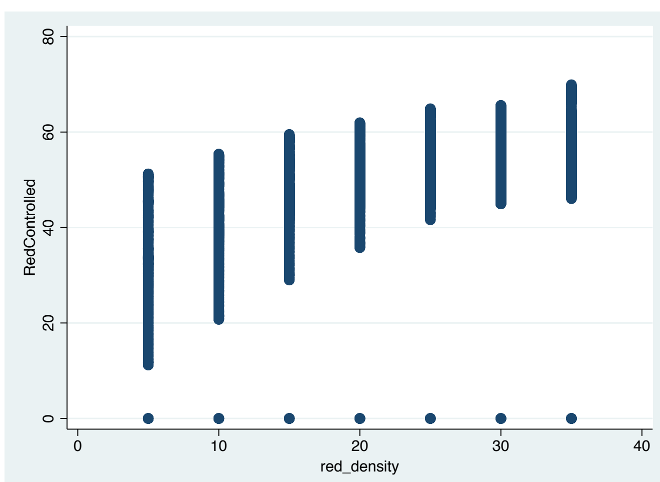


Figure 5.1 – Comparison of Red Terrain Controlled with Initial Red Density (260 Bi-weeks)

A "sweet spot" of 7 to 12 percent difference in initial force ratio between blue and red produced the richest variation in the percentage of territory gained by the insurgents after 10 years (Figure 5.2, below):

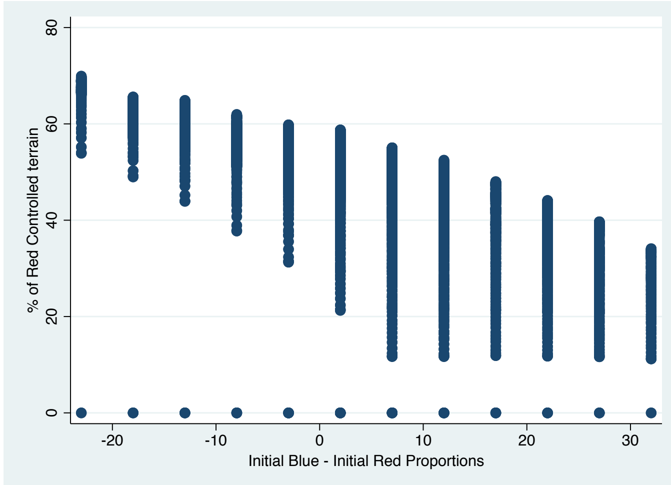


Figure 5.2– Red Controlled Territory as a Function of Blue – Red Initial Proportions

The unemployment rate is expected to increase the percentages of red territory gained and red victories through the mechanism of increased red recruitment. In fact, this was the case. The chart below shows the number of red target kills (i.e., blue deaths) increasing as the unemployment rate increases for three representative values (Figure 5.3).

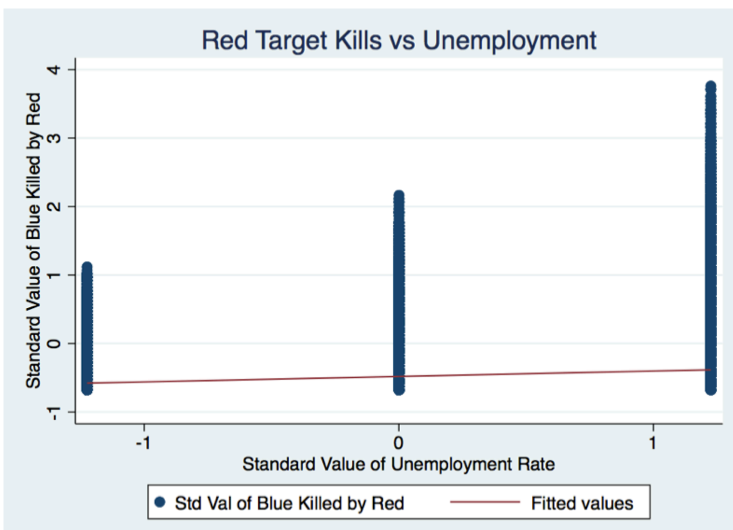


Figure 5.3 – Unemployment vs. Red Target Kills (Blue Deaths)

Territory gained by red also increases with the unemployment rate, thorough the same mechanism as increased numbers of insurgents. Below is a plot of territory gained by red for the same three rates of unemployment (Figure 5.4).

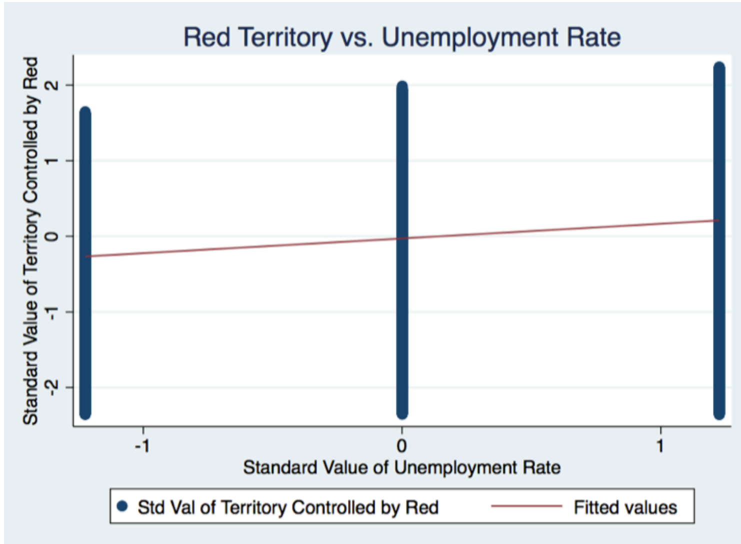


Figure 5.4 – Territory Controlled by Red as a Function of Unemployment

However, force ratios tended to overshadow the impact of unemployment. Dynamically, blue conversions and blue paradrops have the most impact on local force ratios, and the most extreme effect are in the urban scenarios, where Blue forces, conversions and paradrops are all concentrated in the predominantly urban terrain. Obviously, allowing conversion of government supporters to soldiers adds to the force strength of blue and helps the blue side. Similarly, the increased mobility of Blue and addition of Blue reinforcements from third countries further helps the government cause.

The runs of the CGW model varied the effect of Blue conversions and Blue paradrops (or other notional air mobility) so those variations could be distributed over all three terrain scenarios (urban, smooth rural, and rough rural). Since this is a dynamic feature of the model (as opposed to simply varying the initial force ratios), the effect of allowing for Blue conversions and paradrops can be clearly seen in some cases. Table 5.1 shows an extreme example of how Blue conversions and paradrops impacted the winner at 10 years in one set of initial conditions in the urban CGW scenario.

Table 5.1 - Effect of Blue Advantages at 10 years in an Urban scenario.

Winner	unemp rate %	weeks	govt-legit
Urban CGW no Blue conv no Blue paradrops			
Red	5	260	0.823
Red	6	260	0.848
Red	7	260	0.841
Red	8	260	0.842
Red	9	260	0.857
Urban CGW yes Blue conv no Blue paradrops			
Stalemate	5	260	0.811
Stalemate	6	260	0.835
Stalemate	7	260	0.845
Stalemate	8	260	0.843
Stalemate	9	260	0.849
Urban CGW yes Blue conv yes Blue paradrops			
Blue	5	260	0.904
Blue	6	260	0.877
Stalemate	7	260	0.902
Stalemate	8	260	0.896
Stalemate	9	260	0.899

The models were less sensitive to the government legitimacy subroutine. One would expect that increasing government legitimacy would strengthen it against the threat of rebellion, and indeed, the models were constructed with this feature in mind. This is a key hypothesis of grievance models of civil war (Berman et al, 2014) (Buhaug et al, 2014).

In any case, an initial government legitimacy parameter was incorporated in the models primarily to introduce dynamic variation independent of the terrain scenarios. While some researchers look at legitimacy strictly from a civil governance standpoint—"trustworthiness" and "procedural justice" (Levi, et al, 2009)—others (Weatherford, 1992) (Gilley, 2009) include the broader sense of legitimacy in the context of overall satisfaction with the government, to include citizens' attitudes and behavior ("views of legality, views of justification, and acts of consent"). Gilley's indicators of legitimacy are six attitudes: citizens' evaluation of the state's respect for individual rights, confidence in police, confidence in civil service, satisfaction with democratic development, evaluation of the current political system, and satisfaction with operation of democracy; and three behaviors: use of violence in civil protest, voter turnout, and quasi-voluntary taxes (Gilley, 2009, Appendix p. 4). As it turned out, the effect of government legitimacy was generally mild compared to the other parameters. In one test, it was only weakly significant ($p < 0.07$) using pooled data (Table 5.2).

Table 5.2 – Pooled Regression of Blue Victory on Selected Variables

Variable DV BlueVictory		
IV	**Coefficienct**	**Std Err (Rob.)**
redpop	0.0011***	0.0042
bluepop	-0.061***	0.0045
govtlegit	-1.085*	0.599
unempl	-0.075***	0.011
constant	29.6***	5.45

CGW Sample Test
Pooled Linear Regression
Number of obs = 1300
Robust Standard Errors

F(4, 1295) = 6090.58
Prob > F = 0.000
R-squared = 0.4619
Adj R-squared = 0.4619
Root MSE = .42858

Comparison of Insurgencies with the Models

The CGW model was compared to several examples of guerrilla warfare in the post-World War II period. The specific scenarios were selected as representative of post-WWII insurgencies and civil wars that proliferated in the latter half for the 20th century and provided much of the impetus for ideas about Fourth Generation War. Each scenario shows the relationship between the outcome predicted by the model and the outcome as documented in the COW databases. The inputs are :

1) The predominate terrain of the area of the insurgency with an approximation of the degree of urbanization at the time of commencement. Terrain is adjusted to fit the geography of the scenario in terms of the approximate percentage of smoothing. City number and radius are adjusted to give the approximate level of urbanization in the game space.
2) Unemployment rate, adjusted to low, medium, or high to adjust for the general level of poverty.
3) Government legitimacy, input at numerical values approximating low, medium, or high.
4) The model is then run for the historical number of bi-weeks that the conflict lasted, as recorded in COW.

Initial force ratio is normally not input—the historical data for both sides is often not available, the exceptions being Malaya and Vietnam Phase 2. Since the model was calibrated to produce the most variation at a difference of 7% between the opposing forces, .for scenarios where initial force sizes are not available, red density is initialized at 5% and blue density at 12%.

The outputs were selected primarily because of the availability of historical data with which to compare. They are:

1) Red-to-Blue combatant death ratio (Blue target kills divided by Red target kills)

2) Identity of the victor, given as the percentage of victories for one side or the other, or stalemate, of all runs with those input parameters. The outputs from the model are then compared to the historical force ratio and victor identity in each insurgency scenario.

<u>Algeria 1954 – 1962</u>

This is an example of insurgency against a colonial power. Knauss (1977) argues that the Algerian peasantry, which "formed the rank and file of the *Armée Nationale de Liberation* (the A.L.N.)" from the very beginning had never accepted the colonial French government as a legitimate governing power. Based on the physiography of Algeria, the rural smooth version of CGW was selected for comparison. The area of northern Algeria, where most of the fighting took place, was about 25% urban in 1954 (Sutton, 1969). Although 8 of 15 "Departments" (areas) were urbanized, this only accounted for about a quarter of the land area. According to Knauss, most of the fighters operated in the countryside, although most of the attacks took place around Algiers. The approximate urban area was thus modeled to reflect about 25% of the gamespace as urban, since the initial fighting would occur on the borders between urban and rural gamespace.

Employment was also a serious grievance, the French colonists and their supporters having taken "'the best land available and the land most suitable for irrigation,' driving thousands of Algerian peasants into the marginal status of seasonal laborers, sharecroppers, agricultural laborers on French settler farms, or landless people" (Knauss, p. 66). Therefore, the unemployment rate was varied at a high value (0.07 – 0.08).

Johnson (2015) argues that despite mostly battlefield defeats, the rebels won the moral high ground by highlighting French human rights abuses and steadfastly focusing international attention on health and humanitarian issues (p. 3). Initial government legitimacy was varied between very low (0.4) and medium (0.6). The war ended with approximately 18,000 and 14,000 deaths on the French and ALN sides, respectively, lasting about seven and half years (191 bi-weeks) (Sarkes, et al, 2010).

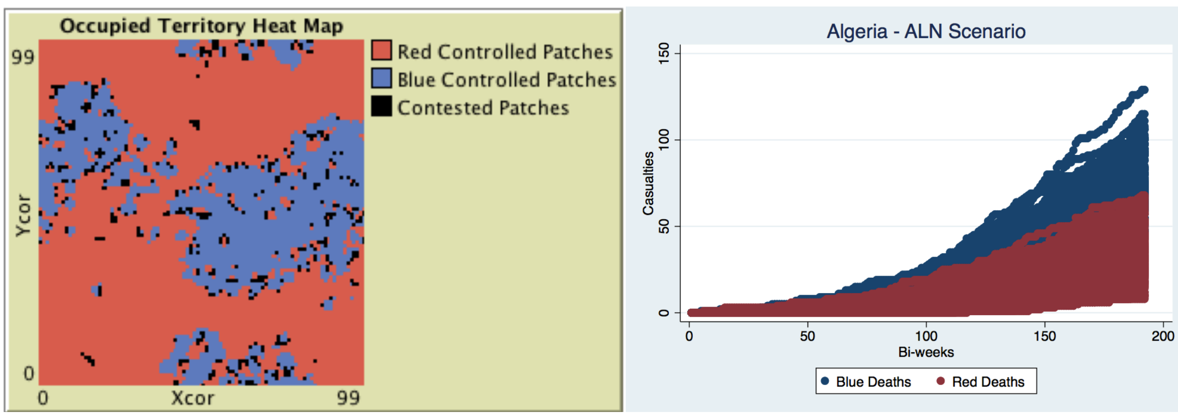


Figure 5.5 – Algeria – ALN Scenario

Table 5.3 – Algeria – ALN Scenario

Conditions	Model Inputs
Terrain	Rural, Smoothness 90
Initial Gov't Legitimacy	0.4 – 0.6
Urbanization	25%
Unemployment	0.07 - 0.08
Blue Conv/Paradrops	FALSE or TRUE/TRUE
Length of Conflict	192 Bi-weeks

Results	Model Outputs	COW Data
Casualty Ratio	0.51 (mean)	0.78
Victory condition	Red Victory (0.46) Stalemate (0.49)	Red Victory

Vietnam, Phase 1, 1960 – 1965

The National Liberation Front (Viet Cong) waged an insurgency against the Republic of Vietnam government in Saigon, who were assisted by the U.S. with training, limited participation, intelligence and psychological operations support.

Mitchell's analysis (1968) repudiated the idea of poverty as an impetus for rebellion. In fact, he reported that "inequality of land distribution in Vietnam is positively associated with government control." In other words, the areas with the most inequality were the post pro-government. As for the impact of good governance, Maranto and Tuchman (1992) argue that, "Decisions [by the peasants] about whom to support depended less on ideology than the package of goods offered by each side" (p. 260). Figure 5.6 below illustrates how the political performance of North Vietnam overwhelmed that of South Vietnam before and after the American intervention (Kugler, et al, 2009). Moreover, the addition of foreign military aid to both sides was significant, although not enough to tip the advantage in power to South Vietnam and the Americans. Nevertheless, even government (or rebel) capacity to provide goods and services competed with the villagers' physical security and their perception of who was winning. Indeed, the concept of legitimacy is often tied with physical security—if a government can't protect its citizens, its legitimacy is in serious question. Often, political power as indicated by government capacity often goes hand and hand with physical security. A government that is efficient in extraction of resources typically has the power not only to provide resources but to ensure physical security as well, authoritarian types even more so (Cheibub, 1998).

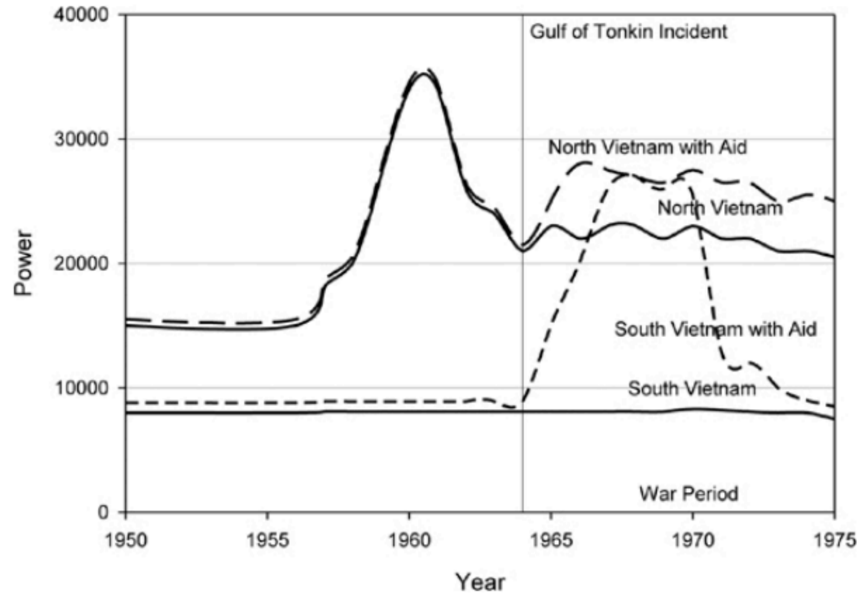


Figure 5.6 – North and South Vietnam Power (Kugler, et. al., 2012)

The terrain of South Vietnam contains a mix of mountains, hills and plains. Arable land comprises only about 20% of the country, but low-lying river deltas make about half of the terrain qualify as "smooth." Therefore, terrain is set with a moderate smoothness of 50%. Degree of urbanization follows Smith and Scarpaci (2000) (see Figure 5.7) and rose from about 20% to 25% in the period studied; it is initialized at 22% in the model.

Government corruption was endemic. The Republic of Vietnam (South Vietnam) government was widely known as a state that was "autocratic, repressive, and corrupt," but more importantly, unwilling and resistant to reforms (Hazelton, 2018). Therefore, government legitimacy was initially set at 0.4. As a proxy for poverty, unemployment is high at 0.07.

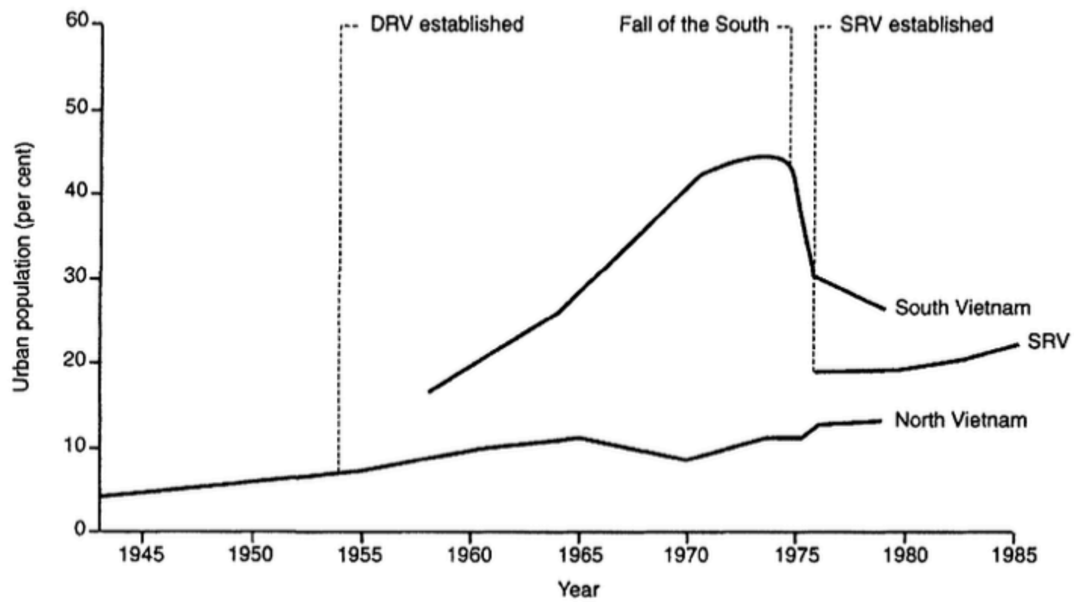


Figure 5.7 – Urbanization in Vietnam, 1945 – 1985 (Smith & Scarpaci, 2000)

The Vietnamese had use of American air support for paradrops, but those operations were rare, so paradrops are run in the model at both False and True.

In the period from 1960 until the American escalation in 1965, war deaths on the government side were estimated at 23,300 and 76,900 on the rebel side. There were relatively few American war deaths during this pre-escalation period, at 506. This phase of war in Vietnam lasted five years and one month, about 133 bi-weeks (Sarkes, et al, 2010).

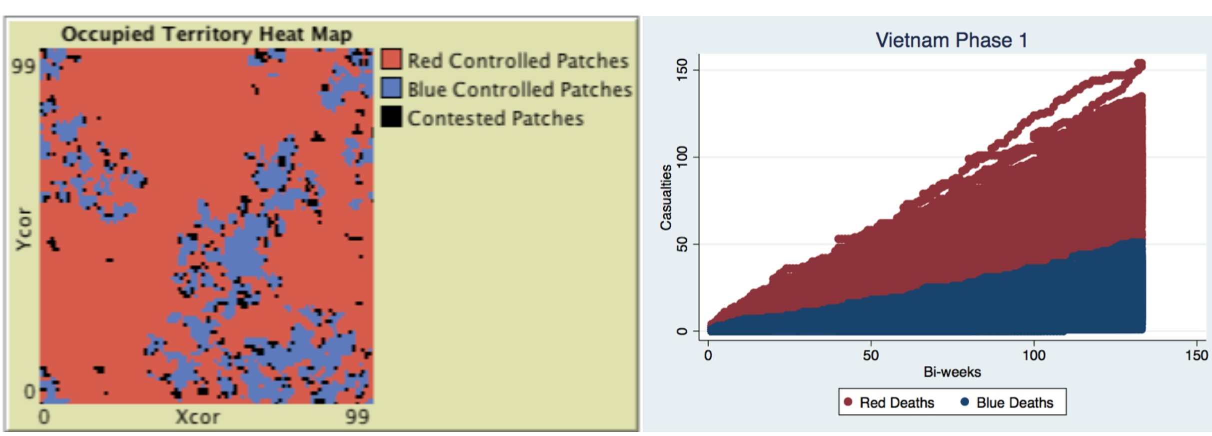


Figure 5.8 – Vietnam Phase 1, 1960 – 1965

Table 5.4 – Vietnam Phase 1, 1960 – 1965 Model Parameters

Conditions	Model Inputs
Terrain	Rural, Smoothness 40
Initial Gov't Legitimacy	0.04
Urbanization	22%
Unemployment	0.07
Blue Conv/Paradrops	FALSE or TRUE/TRUE
Length of Conflict	133 Bi-weeks

Results	Model Outputs	COW Data
Casualty Ratio	2.54 (mean)	1.63
Victory condition	Stalemate (0.42) Red Victory (0.58)	Stalemate

Here, the model produced an outsized number of Red deaths, almost twice that in the historical data. However, it produced the correct victory condition, Stalemate, 42% of the time. Some argue that South Vietnam would have lost before 1965 if the U.S. hadn't provided advisory and air mobility support, which may account for some of the difference between the model and the historical data.

<u>Philippines, 1972 – 1992.</u>

This is the longest insurgency in the COW Intra-State War database, at 20 years (527 bi-weeks. The rebels ("New People's Army," or NPA) were a union of a remnant unit of the Hukbalahap insurgency and the Communist Party of the Philippines (CCP). Government corruption was a major motivating factor for the insurgents, which drew strong support from local populations. According to Mediansky (1986), "widespread abuse of the population by the government's civilian and military functionaries [was] a major factor contributing to the support of the NPA." Moreover, the brutal behavior of government forces along with "the absence of legitimate and effective channels for the expression of social, political, and economic grievances…turned many towards the NPA" (p. 9). Rosenberger (1987) notes that the Philippine economy was generally depressed. Most economic proposals for fighting the communist insurgency focused on increasing exports, particularly in the depressed sugar-producing areas of Negros, "where malnutrition and other maladies [were] attractive targets for CPP/NPA exploitation" (p. 200). Therefore, unemployment was set at a high level. By the end of 1992, government forces suffered an estimated 9,000 deaths, in contrast to the NPA force's estimated 22,000 deaths, and the result was a stalemate (Sarkes et al, 2010).

The model was initialized using the rural-rough terrain settings. It had increased Blue kill rate and increased Blue collateral damage to simulate government brutality. Unemployment was set at a neutral value and initial government legitimacy between 40 and 60 percent, which decreased to a mean of 0.446 over the course of the runs. The model was run for 527 bi-weeks.

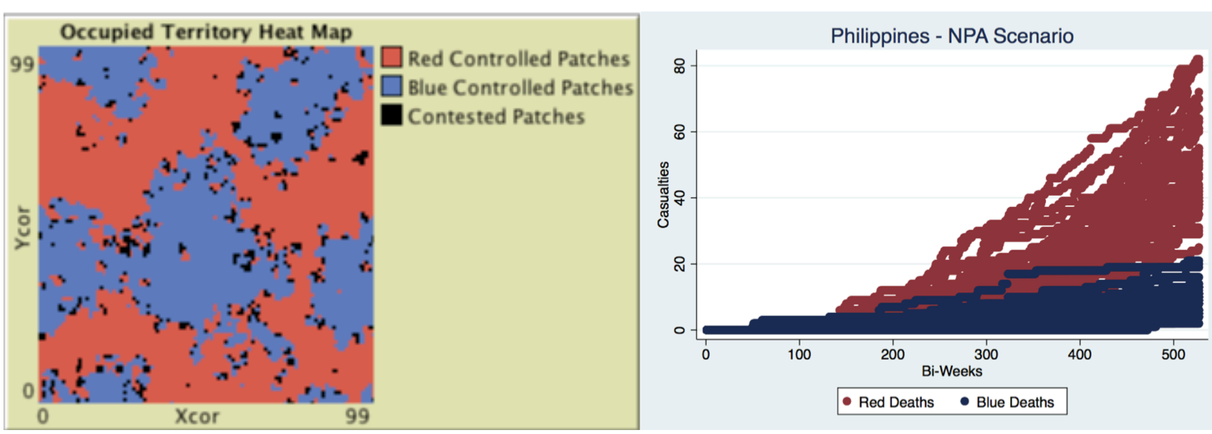


Figure 5.9 – Philippines – NPA Scenario

Table 5.5 – Philippines – NPA Scenario

Conditions	Model Inputs
Terrain	Rural Rough
Initial Gov't Legitimacy	0.4 - 0.6
Unemployment	0.07 – 0.08
Blue Conv/Paradrops	TRUE
Length of Conflict	527 bi-weeks

Results	Model Output	COW Data
Casualty Ratio	5.43 (mean)	2.44
Victory condition	Stalemate (92.2) Red Victory (7.8)	Stalemate

Here the model predicted the correct victory outcome 92% of the time, but produced Red Victory 8% of the time. The actual death ratio as recorded in COW (22,000 insurgents to 9,000 government) was 2.44 to 1, while the model produced an average casualty ratio of Red deaths to Blue deaths of 5.43. The excessive red death may be associated the erroneous Red Victory prediction, which was output in 8% of the model runs.

<u>Cuba, 1958-1959</u>

Castroist rebels (*Fidelistas*) overthrew the Batista government. Blanco (1994) argues that despite numerous infrastructure improvements designed to improve the life of most Cubans, the regime was largely viewed as corrupt and brutal to its enemies, and "Batista's attempts to enhance his legitimacy through elections [and public works projects] were largely perceived as a show" (Blanco, 1994). Thus, initial government legitimacy was input as "low" (0.4).

Poverty does not appear to have been a major influence. Farming and industrialization provided most Cubans with year-round employment, despite some authors' emphasis on the seasonality of the sugar-cane harvest (Ruiz, 1968). Batista's army was comprised mostly of *campesinos* (field laborers) unable to find work elsewhere, so this acted as shock absorber for economic downturns, and some were even made officers by Batista to try to bolster his support from the rural areas (Blanco, p. 50). Thus, the unemployment rate was set at a neutral value (0.05). Paradrops were set at TRUE to better simulate the large-scale government attacks against rural insurgent outposts.

For calculating the proportion of urban terrain for the model, a study on the historical urbanization of Cuba was used (Ebanks, 1998). The population of Cuba in 1959 was approximately 7.005 million, with around 20% living in Havana. Urbanization was high at 55% in 1960, with most of the urban population living in 4 cities, Havana, Santiago, Camaguey, and Holquin. This would make the urban population somewhere around 3.85 million, with about 770,000 living in Havana.

By the end of the rebellion, which lasted a little over 7 months (16 bi-weeks) there were roughly 2,000 deaths on the government side, and about 1000 deaths on the rebel side. (Sarkees et al, 2010).

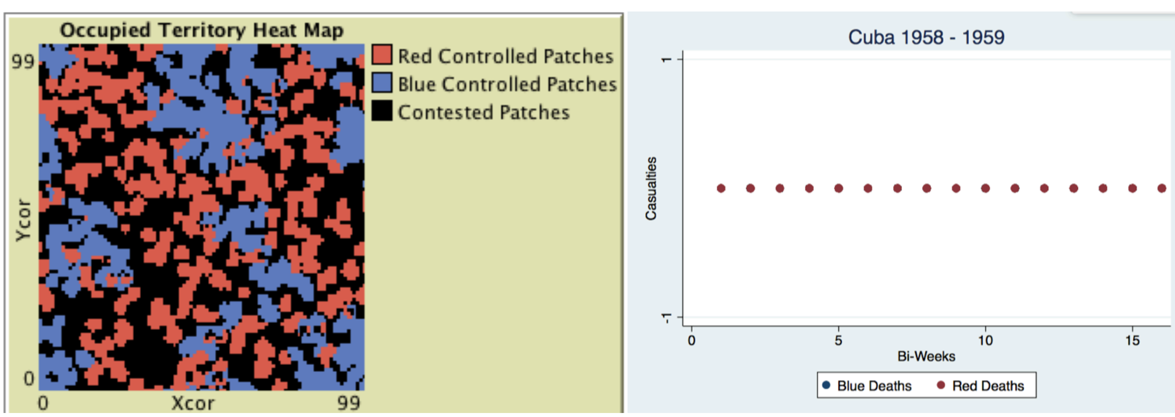


Figure 5.10 – Cuba Scenario (First Runs)

Table 5.6 – Cuba Scenario (First Runs)

Conditions	Model Inputs
Terrain	Rural/Urban, Smoothness 0.7
Initial Gov't Legitimacy	0.04
Urbanization	0.55
Unemployment	0.05
Blue Conv/Paradrops	FALSE/TRUE
Length of Conflict	16 Bi-weeks

Results	Model Output	COW Data
Casualty Ratio	Undefined	0.50
Victory condition	Stalemate (1.0)	Red Victory

In this scenario, the model performed particularly poorly. The duration of the simulation was too short to produce casualties due to the slow initial movement of the agents and blue spawning in the cities. However, the recruitment sub-model drove robust Red recruitment, with conversions from Green to Pink averaging at about 81.3 per bi-week out of 3,000 total agents, and Pink to Red about 5.1 per bi-week.

The COW Intra-State War database shows the insurgency beginning on the May 24, 1958 government attack with some 10,000 soldiers on the *Fidelista* strongholds in the Sierra Maestra mountains. The Cuba scenario was then programed for a second set of runs, this time with the constraint removed that soldiers begin their initial positions in the cities. Also, some authors have noted the country was in turmoil, from the time Castro and his supporters returned to the island on December 2, 1956. Numerous small attacks by insurgents had occurred throughout 1957 and early 1958. Therefore, the simulation was run again, this time using 54 bi-weeks, the length of time from Castro's return to the overthrow of Batista on January 2, 1959.

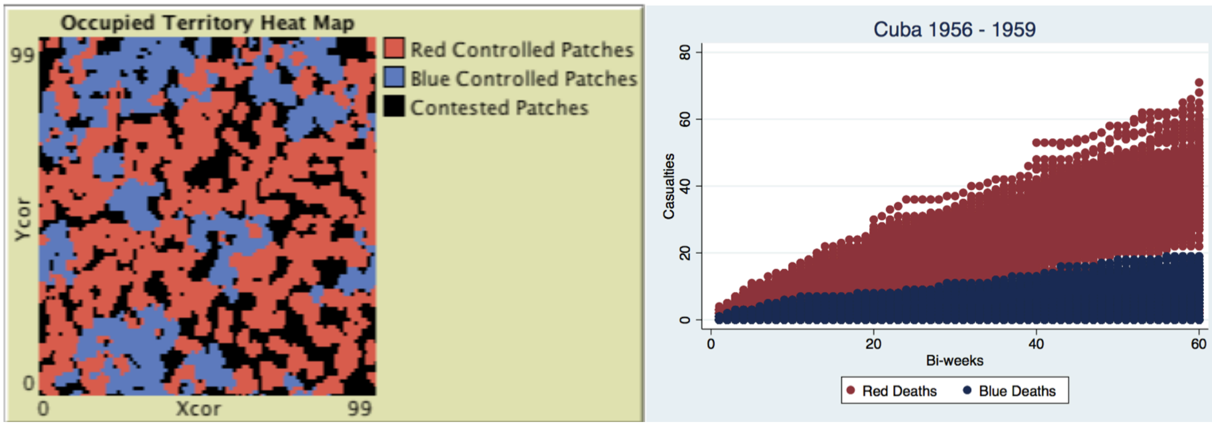


Figure 5.11 – Cuba Scenario (Second Runs)

Table 5.7 – Cuba Scenario (Second Runs)

Conditions	Model Inputs
Terrain	Rural/Urban, Smoothness 0.7
Initial Gov't Legitimacy	0.04
Urbanization	0.55
Unemployment	0.06
Blue Conv/Paradrops	FALSE/TRUE
Length of Conflict	54 Bi-weeks

Results	Model Output	COW Data
Casualty Ratio	3.15 (mean)	0.50
Victory condition	Blue Victory (0.37) Stalemate (0.63)	Red Victory

The results of this scenario are not in line with the historical record. The simulation produced the Blue victory condition 37% of the time and Stalemate for the remainder. The casualty ratio in the model was opposite of the COW data, which records that the Cuban government suffered 2,000 deaths while the rebels had half that number. In Cuba, the government started with an advantage of forces, but the insurgents won by winning local victories, capturing public opinion, and forcing Batista to resign and flee.

Malayan Rebellion, 1948 – 1957

This is one of the few cases of "Blue" victory in an insurgency, at least in the initial period. The insurgency was fueled by expectation that after Japanese rule democratization would occur, and disappointment and by resentment of renewed British support of the rajahs and sultans. In this sense it was a crisis of government legitimacy. Although portrayed by some as a "hearts and minds" campaign, it was in fact mainly a two-pronged strategy of political support from the Malays and often brutal physical control of the rural Chinese population through forced relocation. Poverty appeared have little role in fueling the insurgency—in fact, the relocations themselves produced poverty in the form of Chinese ghettos called the "New Villages" (Strauch, 1981). Poverty was therefore set at a neutral value.

Degree of urbanization was unusually high for an agricultural society—35.1 percent of the population lived in an urban center greater that 1,000 population, while about 27.5 percent lived in cities with populations greater than 10,000. According to the 1947 census, out of a total population of about 5.49 million, over 2.05 lived in urban areas. (Cooper, 1951).

British success in Malaya was hard to duplicate: their most important advantage was that the rebellion was overwhelmingly confined to the Chinese population, less than half the total population of the Malayan mainland. In addition to the strategies of repression and relocation of the Chinese, the British enjoyed a substantial force advantage. 40,000 Commonwealth and allied soldiers backed up by 80,000 police and 250,000 home guard faced an insurgency that never numbered more that 8,000 (Newsinger, 1994). Thus, the initial force ratio input into the model favored the British by 5:1. "Moreover, the British success at 'divide and rule' and the [Malaysian Communist Party's] failure to win support among the Malay [people] was to prove fatal" (p. 24).

The British granted independence to Malaya in 1957 with the intent of maintaining rule "through the agency of the traditional Malay rulers," but eventually withdrew in the late 1960s due to conditions at home. The rebellion resulted in approximately 2,400 government and 7,600 rebel deaths and lasted over 9 years and two months (239 bi-weeks).

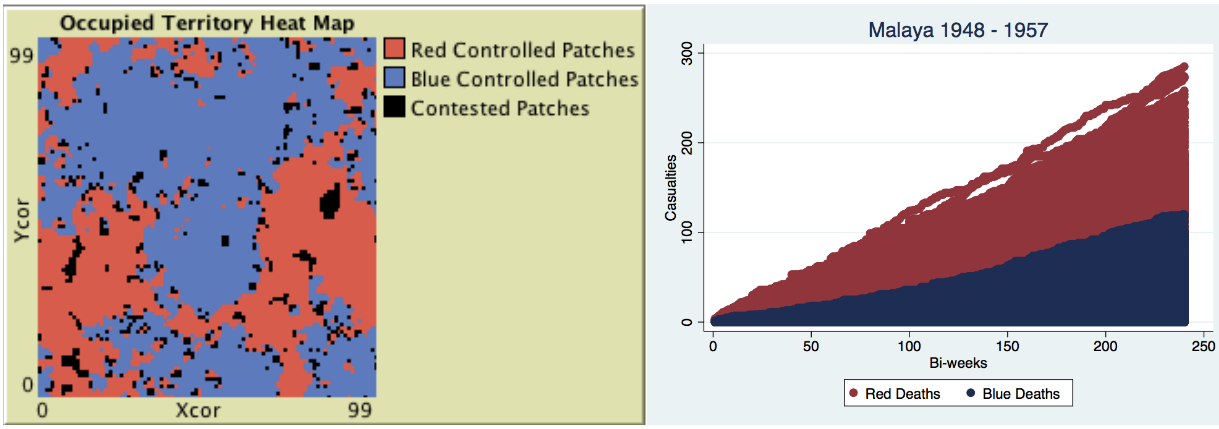


Figure 5.12 – Malaya Scenario

Table 5.8 – Britain vs. Malaya Rebels

Conditions	Model Inputs
Terrain	Rural Rough/Urban
Initial Gov't Legitimacy	0.75
Urbanization	0.31
Initial Force Ratio	40:8 (Blue)
Unemployment	0.05
Blue Conv/Paradrops	TRUE/TRUE
Length of Conflict	239

Results	Model Output	COW Data
Casualty Ratio	2.15 (mean)	2.79
Victory condition	Blue Victory (0.84) Stalemate (0.16)	Blue Victory

As is shown in Table 5.6, the model underestimated the casualty ratio, over-predicting Blue deaths by about 45%. The model produced a Blue Victory most of the time due to the high number of Red deaths and Blue acquisition of territory.

Vietnam Phase 2, 1965-1972

This phase of the Vietnam War, with escalation occurring until 1968, and then "Vietnamization" thereafter makes for an interesting look at the impact of foreign military aid. Although not a pure insurgency, but more of a civil war with sporadic periods of conventional battle (most notably the Tet Offensive of 1968 and the Spring Offensive in 1972), this period was characterized by a large foreign troop buildup in support of the government of the South, followed by a gradual drawdown of foreign troops while simultaneously building up the South Vietnamese army. The simulation takes place in the South, where almost all of the ground fighting took place, although North Vietnam moved troops and supplies to its allies in the South through neighboring Cambodia and Laos.

The model was configured both with and without foreign military assistance. Although North Vietnam received foreign military assistance from the USSR, the COW database does not contain data for their participation, meaning that deaths of USSR personnel were less than 2,000. The same terrain parameters in Vietnam Phase 1 are used, but the urbanization rate ranged between 25% and 43% during this period, so the city area in the model is increased to the mean, which is 34%. Government legitimacy remains the same as the Phase 1 parameter, 0.4. Unemployment remains high at 0.07.

The U.S. increased the number of forces in Vietnam through 1968, after which President Nixon's "Vietnamization Policy" took effect, gradually drawing U.S. Forces down again (Figure

5.13). The model has no way of decrementing Blue forces other than attrition or recruitment. However, since Nixon's avoid policy was not to withdraw U.S. soldiers until they could be replaced by ARVN forces, spawning is halted in the model after Dec 31, 1968 (101 bi-weeks) and Blue overall force strength is maintained thereafter (except what is lost or gained through battle or recruitment). Table 5.9 shows the rate of buildup and drawdown. One may note that the total number of forces fighting for the South decreased at a mean rate of only 4.7% after the Americans began withdrawing in 1969.

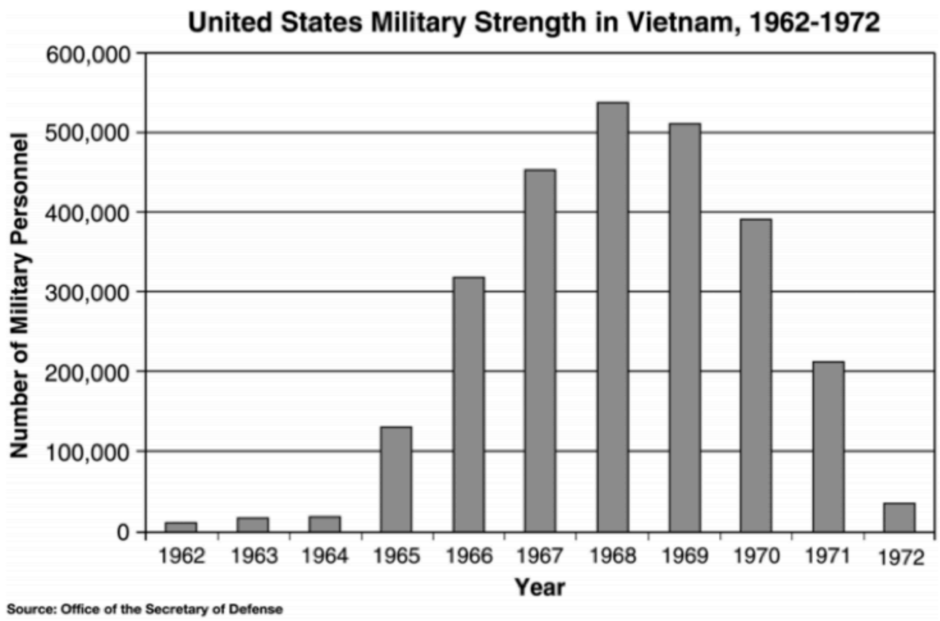


Figure 5.13 – U.S. Military Strength in Vietnam, 1962 – 1972

Table 5.9 – Military Strength of South Vietnam by Contributor, 1964 – 1973 (American War Library, 2008)

Year	U.S.	Aust.	Korea	New Zeal	Philip	Thai	Tot. Foreign	% Change	S. Vietnam	Total	% Change
1964	23,300	198	200	30	20	--	23,748	46%	514,000	537,748	107%
1965	184,300	1,560	20,620	120	70	20	206,690	770%	642,500	849,190	58%
1966	385,300	4,530	25,570	160	2,060	240	417,860	102%	735,900	1,153,760	36%
1967	485,600	6,820	47,830	530	2,020	2,200	545,000	30%	798,700	1,343,700	16%
1968	536,100	7,660	50,000	520	1,580	6,000	601,860	10%	820,000	1,421,860	6%
1969	475,200	7,670	48,870	550	190	11,570	544,050	-10%	897,000	1,441,050	1%
1970	334,600	6,800	48,450	440	70	11,570	401,930	-26%	968,000	1,369,930	-5%
1971	156,800	2,000	45,700	100	50	6,000	210,650	-48%	1,046,250	1,256,900	-8%
1972	24,200	130	36,790	50	50	40	61,260	-71%	1,048,000	1,109,260	-12%
1973	50	--	--	--	--	--	50	-100%	1,110,000	1,110,050	0%
									Average after 1968		-4.7%

This phase of the war lasted 266 bi-weeks, until the overthrow of the South Vietnamese government in April, 1975. Resulting deaths were recorded in COW as 700,000 for the North (including Viet Cong) and 254,257 for the Army of Vietnam. The U.S. and its allies comprised an additional 64,685 deaths, for a total of 381,058 Blue deaths, making the Red/Blue ratio equal to 1.84.

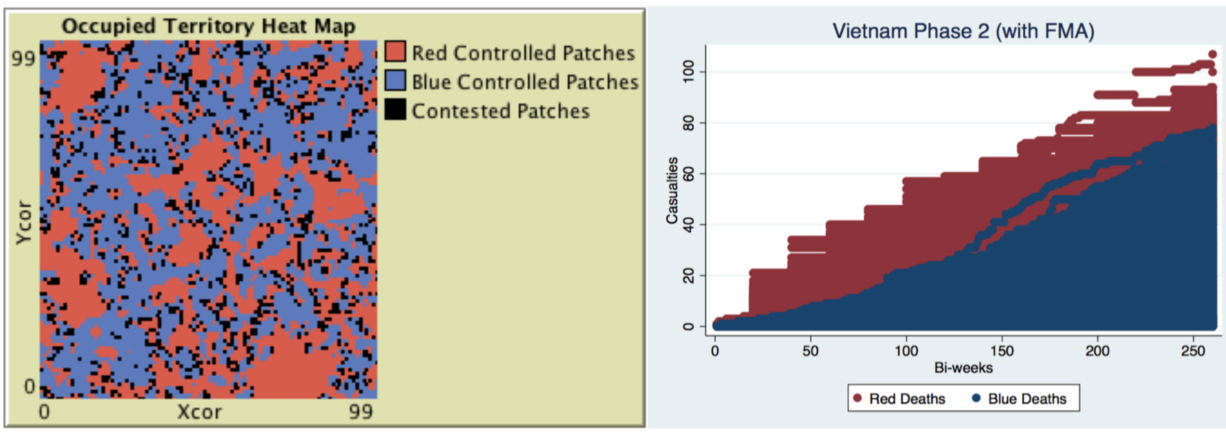


Figure 5.14 – Vietnam Phase 2 Scenario (with Third Country)

Table 5.10– Vietnam Phase 2 Scenario (with Third Country)

Conditions	Model Inputs
Terrain	Rural, Smoothness 50%
Initial Gov't Legitimacy	0.4
Urbanization	34%
Initial Spawn Rate	10/bi-week
Unemployment	0.07
Blue Conv/Paradrops	FALSE or TRUE/TRUE
Length of Conflict	266 Bi-weeks

Results w/o FMA	Model Output	COW Data
Casualty Ratio	2.83 (mean)	N/A
Victory condition	Red Victory (0.88) Stalemate (0.12)	N/A

Results w/ FMA	Model Output	COW Data
Casualty Ratio	1.65 (mean)	1.84
Victory condition	Stalemate (79%) Blue Victory (21%)	Red Victory

Without foreign military assistance (FMA) the model predicts a Red Victory in 88% of the runs. The casualty ratio was reported as 2.83. Since this situation did not occur in history, there is no COW data for comparison.

With foreign military assistance in the form of additional allied forces, the model reported a casualty ratio of 1.65 and predicted a Blue victory 21% of the time and a Stalemate 79% of the time. Yet, in the historical data, the rebel forces were victorious. This might be explained by the fact that the model does not assume spawning on the Red side. In actuality, the North Vietnamese and rebel forces recovered from their losses in 1972 and increased their numbers. Two and half years later they launched their spring offensive, which this time was successful. Also, there was a 12% decline in total forces in 1972 as the last of the Americans withdrew, which is not reflected in the model. Finally, American airpower had been withdrawn which reduced mobility for South Vietnamese forces. This is modeled as paradrops, which continue in the CGW simulation. The performance of the model in this scenario suggest that future versions should include other mechanisms for measuring military power, such as capacity.

Macro Comparison of the CGW Model with COW Data

The CGW model was compared to the COW Intra-State War Data (Sarkees, 2010), which tracks war within countries. The original data set contains 334 intra-state wars. Of those, 38 were civil wars for central control initiated between 1946 and 1990, which are the general definition for insurgency warfare simulated by the CGW agent-based model.

The number of weeks of conflict was regressed on for a comparison with the CGW model. One case, the Chinese Civil War Phase II was an outlier with a high number of battle deaths (just under standard deviations from the mean). Another case, Philippines and the National People's Army, was an outlier in time at 597 bi-weeks of duration. The table below presents the results of the regression of the combined CGW model deaths across 260 bi-weekly periods.

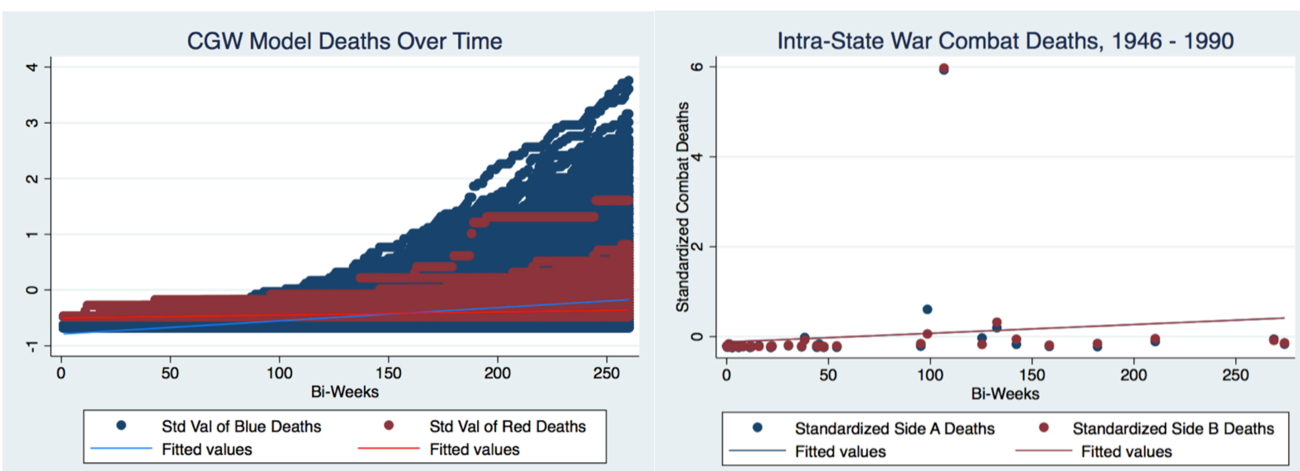
Table 5.11 – Conflict Length Combined CGW (All Scenarios) Compared With COW

DV Bi-Weeks			
	N = 168,480		N = 38
CGW Model IV	Coefficient (Std Err)	**COW Data IV**	Coefficient (Std Err)
zbluetarget	143*** (2.85)	Std Side B Deaths	72.6** (27.9)
zredtarget	59.8*** (0.374)	Std Side A Deaths	7.9 (23.5)
constant	221*** (1.26)	constant	67.0*** (13.5)

***Significant to 0.01 Level
**Significant to 0.05 Level

Here, the signs agree in both the model and the real-world data, and both coefficients have the same approximate order of magnitude, although the model produces about double the casualties found in the real-world data for the same time period. This may indicate that since the model exhibits more casualties per bi-weekly period for each turn in the simulation, the time scale per turn could be approximately doubled for better agreement with the historical record. Moreover, in the model zredtarget, standardized Red target kills, i.e. standardized Blue deaths, are a little over 40% of standardized Red deaths per bi-weekly period. The comparable real-world data reveals that the rate of Side A combatant deaths comprise only about 11% of the rate of Side B deaths per bi-weekly period.

Below is a comparison of scatter plots showing the combatant deaths obtained with the CGW model and those reported by the COW Intra-State War database for civil wars from 1946 to 1990 (Version 5.0, 2016). The high number of blue deaths in the model is primarily generated by the urban scenario. Both rural scenarios generate insurgent deaths of about one-third of the soldier deaths, as compared to about one-eighth in the urban scenario. The outlier in the COW data is the Chinese Civil War Phase II, with about 6 standard deviations of combatant death compared to the mean. One point on the Intra-State War Combat Deaths chart (Philippines vs. the NPA) is omitted to keep the horizontal scales consistent; the Side A and B deaths are -0.034 and -0.035 standard deviations at 527 bi-weeks, respectively.



*One data point at 527 bi-weeks (-0.034, -0.035 combat deaths) not shown for scale.

Figure 5.15 – Comparison of CGW Model Deaths with Intra-State Combat Deaths in COW

Side A and Side B combatant deaths in many Intra-State wars in the data set are roughly equal, as shown by the overlap of several Side A and Side B point pairs. The model tends to overestimate the number of combatant deaths in the latter stages of each conflict.

Additionally, the COW Territorial Change Database (Version 6, 2019) (Tir, et.al., 1998) was compared to the CGW model with respect to the likelihood of Red or Blue victory. A Standardized Value of Territory Exchanged (StdTerrGain) variable was generated from the area of the land exchanged for internal military conflicts from 1946 to 1990. The chart below illustrates the increased variability of the territorial increases in the CGW model compared to the COW data:

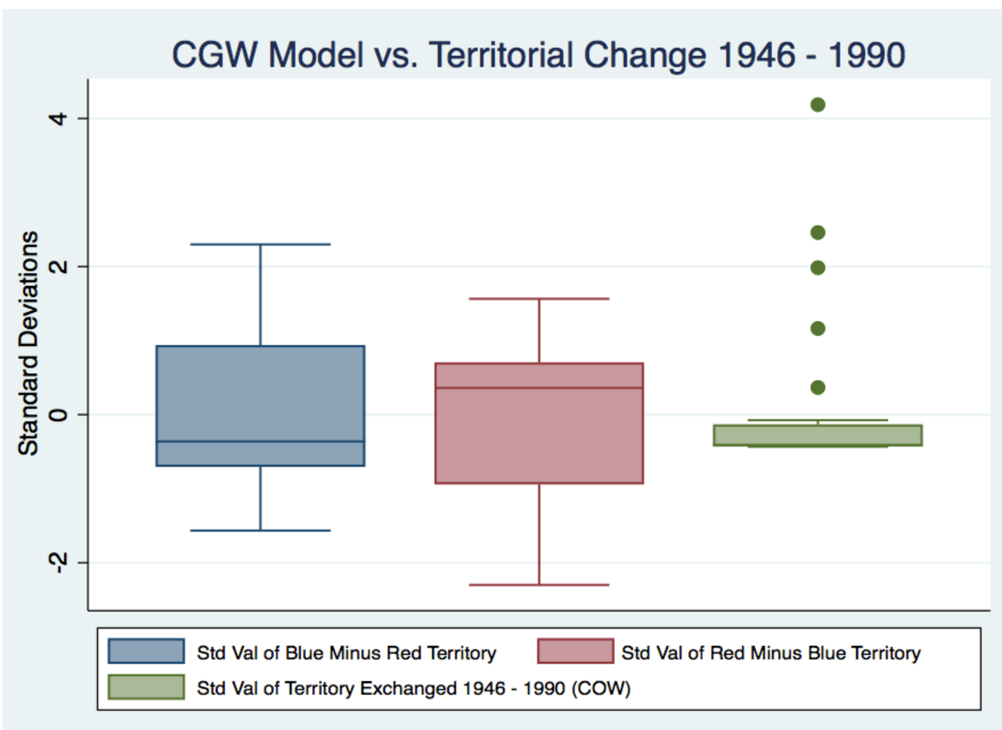


Figure 5.16– Standardized Values of Territory Exchange Compared to COW

Red or Blue victory was then coded based on agreement between the gaining side name and the territorial entity name, and a logit regression of Red victory on Red territory controlled (zredcont). As the table below shows, the CGW model produces territory change with the correct sign and order of magnitude as the real world internal military conflict data. The model somewhat underestimates the increase in log odds of Red victory for each standard deviation of territory gain by 59% when compared to actual territorial change.

Table 5.12 –CGW Model Compared to Red Victory in COW

DV Red Victory (True/False) Logit Regression			
	N= 168,480		N = 34
CGW Model IV	Coefficient (Std Err)	**COW Data IV**	Coefficient (Std Err)
zredcont	4.18*** (0.033)	StdTerrGain	7.13** (3.13)
constant	-4.45*** (0 .030)	constant	1.32 (1.07)

***Significant to 0.01 Level
**Significant to 0.05 Level

Thus, from a macro standpoint, the model predicts the correct sign and order of magnitude of historical combat deaths and territory gained in the most common case, which is Red victory. And, in spite of the fact that the model overpredicts battle deaths—particularly Blue battle deaths, the CGW model can be used as a reasonable baseline for comparing 4/5GW.

Chapter 6 – Results

In this section, the results obtained from comparing the CGW and 4/5GW models are examined. The models performed their purpose of contrasting classic guerrilla warfare with its information-age counterpart, Fourth Generation and irregular Fifth Generation Warfare. Each of the six scenarios (three terrain models each for CGW and 4/5GW) were run for 260 turns, representing 260 bi-weekly periods, totaling 10 years of simulated time. The specification for the comparison of the two models featured two dependent variables that are thought to best represent the important differences between classic guerrilla warfare and modern warfare with 21st century communications technology: Territory Gained and Victory Attained, victory, being defined as one side gaining at least 10 percent more fighters (recruits minus attrition) population AND 10 percent more territory than the opposing side after 10 years. The models output the percentage of territory occupied both graphically (see Figures 6.1 and 6.2, below) and numerically. The specifications are thus:

$Y_1 = \alpha_t + \beta_0 + \beta_i t X_{it}$ where Y_1 = territory gained, and $\beta_i t X_{it}$ are the independent variables denoting Classic Guerrilla Warfare or $4^{th}/5^{th}$ Generation Warfare.

$Y_2 = \alpha_t + \beta_0 + \beta_i t X_{it}$ where Y_2 = bi-weeks to victory by one side or the other, and $\beta_i t X_{it}$ are the independent variables denoting Classic Guerrilla Warfare or $4^{th}/5^{th}$ Generation Warfare.

$Y_3 = \beta_0 + \beta_{it} X_{it}$ where Y_3 is categorical, representing a red victory, a blue victory, a stalemate after 10 years.

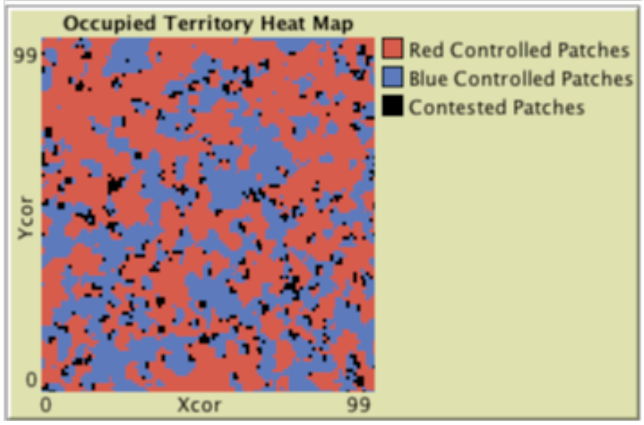


Figure 6.1 – Occupied Territory Heat Map

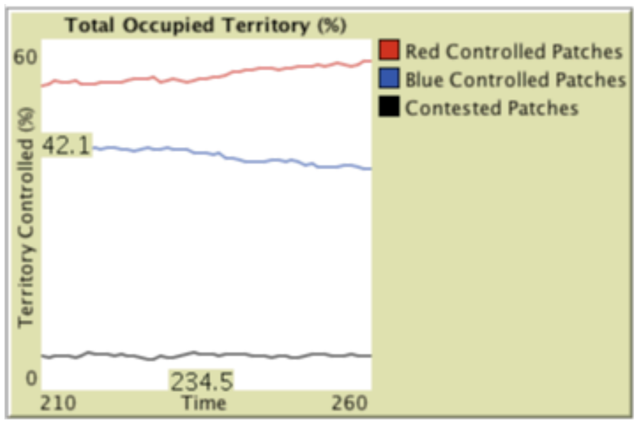


Figure 6.2 – Occupied Territory Over Time

Data

Data were collected at each turn ("bi-week") and panels composed of a cross-section of runs for each of the six scenarios with different variable combinations was generated. These data were then standardized to a mean of 0 and a standard deviation of 1 for consistent comparison of coefficients. Variable Names, Meanings and Range of Values are presented in Table 6.1, below.

Table 6.1 – Variable List

Variable	**Description**	**Range of Values**	**Standardized Variable Name**
Runnum	Run Number (cross-section)	1 to 216	N/A
biweeks	Bi-weekly periods (one turn in model)	1 to 260	N/A
redcont	Territory controlled by Red	0 to 10,000	zredcont
lnredcont	Natural log of Red Territory	1 to 10	N/A
redpop	Population of Red combatants	0 to 1000	zredpop
redtarget	No. of targets killed by Red	0 to 1000	zredtarget
redcollat	No. of civilians killed by Red	0 to 1000	zredcollat
redcomm	Communications range/speed of Red	1 to 2 (CGW), 5 to 10 (4/5GW)	zredcomm
bluecont	Territory controlled by Blue	0 to 10,000	zbluecont
lnbluecont	Natural log of Blue Territory	1 to 10	N/A
bluepop	Population of Blue combatants	0 to 1000	zbluepop
bluetarget	No. of targets killed by Blue	0 to 1000	zbluetarget
bluecollat	No. of civilians killed by Blue	0 to 1000	zbluecollat
bluecomm	Communications range/speed of Blue	1 to 2 (CGW), 5 to 10 (4/5GW)	zbluecomm
unempl	Unemployment rate	4 – 6%	zunempl
initlegit	Initial Government Legitimacy	0.85 or 0.89	zinitlegit
govtlegit	Government Legitimacy	0 to 1	zgovtlegit
blueconv	Allows Cyan Supporters to be converted to Blue	True/False	N/A
bluepara	Allows for Blue Paradrops (CGW)	True/False (True in 5GW)	N/A

A summary of the data output is provided below in Table 6.2 . The standardized equivalents are (variables beginning with "z") are provided in the lower half of the table.

Table 6.2 – Data Summary

Variable	Obs	Mean	Std. Dev.	Min	Max
sheet	0				
scenario	327,600	3.6	1.823657	1	6
runnum	327,600	112.1	69.73091	1	288
biweeks	327,600	130.5	75.05509	1	260
redcont	327,600	4395.071	1731.969	388	8451
redpop	327,600	313.841	111.7717	145	905
redtarget	327,600	30.18767	43.66896	0	301
redcollat	327,600	12.6394	20.49689	0	143
redcomm	327,600	4.6	4.447264	1	15
bluecont	327,600	3135.464	2066.471	451	9263
bluepop	327,600	581.4997	417.3109	313	2709
bluetarget	327,600	9.924615	16.65444	0	136
bluecollat	327,600	2.174994	3.83105	0	34
bluecomm	327,600	4.6	4.447264	1	15
unempl	327,600	4.885714	.7845458	4	6
initlegit	327,600	.87	.02	.85	.89
govtlegit	327,600	83.59731	4.618415	57.72727	89
blueconv	327,600	.5	.5000008	0	1
bluepara	327,600	.7428571	.4370595	0	1
redcontblu~t	327,600	2.238342	1.486747	.0419459	8.984979
bluecontre~t	327,600	1.052244	1.472526	.1112969	23.84021
redpopblue~p	327,600	.6907584	.3635303	.0797342	2.535014
bluepopred~p	327,600	2.061974	1.599144	.3944751	12.54167
victoryred	327,600	.1237912	.3293437	0	1
victoryblue	327,600	.2681807	.4430129	0	1
stalemate	327,600	.6080281	.4881912	0	1
newrunnum	327,600	3712.1	1834.77	1001	6288
redvictime	327,600	25.51926	69.22699	0	260
bluevictime	327,600	26.8593	56.67497	0	260
zredcont	327,600	0	1	-2.313594	2.341803
Zredcollat	327,600	0	1	-.6166495	6.36002

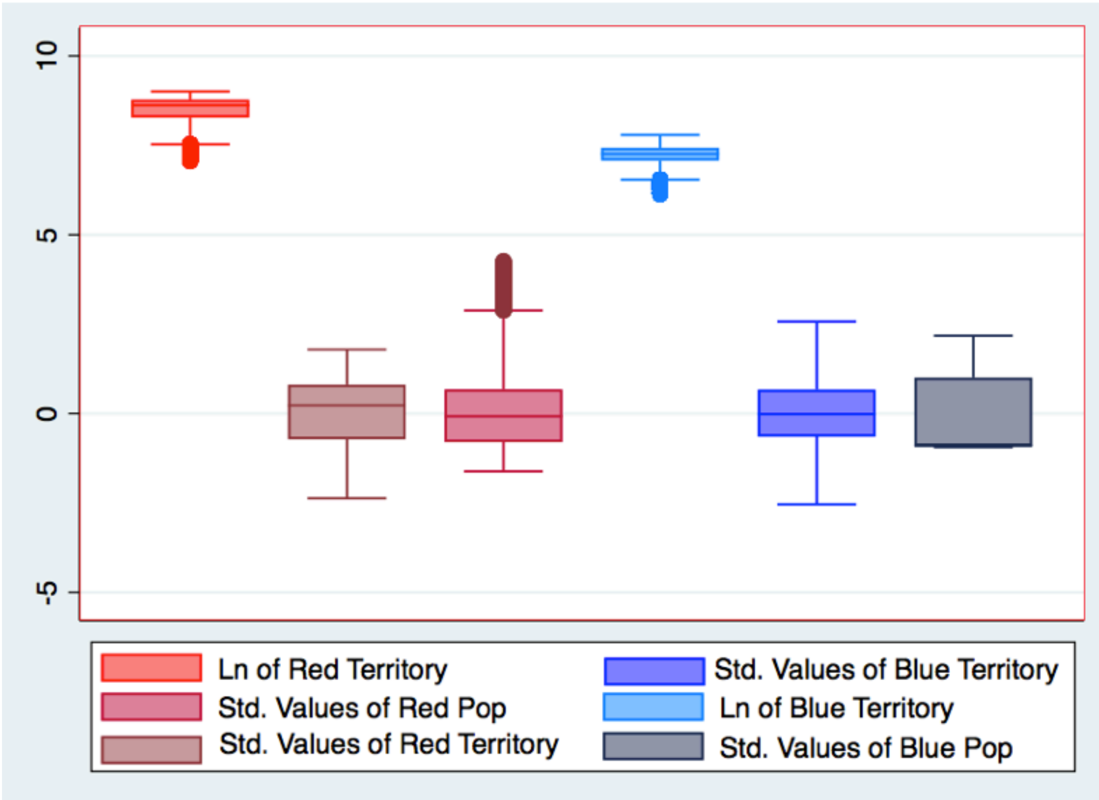


Figure 6.3 – Red and Blue Population and Territory Controlled

A correlation matrix of the independent variables with Red Controlled Territory for each model and each scenario was run to identify potential for multi-collinearity. As expected, Red target kills and Red collateral kills were highly correlated (R = 0.915). The more that Red engaged in combat, the more we would expect collateral kills to increase. Red and Blue target kills were also highly correlated (0.910), indicating the mutual nature of the engagements. Red collateral kills were also correlated with Blue target kills (0.911). Finally, Blue target and collateral kills were highly correlated (0.910). All other correlations were substantially less, except for Blue collateral kills with Red target and Red collateral kills (0.850 and 0.854, respectively). Red Target Kills and Blue Target Kills are highly correlated with each other and with collateral kills. But they are also highly correlated with initial force densities and force ratios in the model. Because they do not provide additional information on territory gained, they are not included in the regression. Blue paradrops are standard in 4/5GW warfare and are not regressed in that model.

Theory 1: Territory Gained as Dependent Variable

In support of Theory I, the table below presents the results of a pooled linear regression on the dependent variable Red Territory Controlled ("zredcont", standardized to a mean of zero and standard deviation of one).

Table 6.3 – Pooled Linear Regression of Standardized Red Territory Controlled on Standardized Variables

Variable **DV redcont** (Standardized)		
IV (Standardized)	**Coefficient**	**Std Err (Rob.)**
zredcollat	-0.0722***	0.00279
zredcomm	-0.0143***	0.00021
zbluecollat	0.097***	0.0032
zbluecomm	-0.056***	0.0021
zunempl	0.264	0.0017
zgovtlegit	-0.101***	0.0018
blueconv	-0.391***	.0035
bluepara*		
constant	0.196***	.0024

Combined Data from All Models

Pooled Linear Regression
Robust Standard Errors

Number of obs	=	327,600
F(6, 327593)	=	6090.58
Prob > F	=	0.000
R-squared	=	0.0913
Root MSE	=	0.95326

*The dummy variable Blue Paradrops is omitted for collinearity (Value "True" in 4/5GW)

If 4/5GW features of warfare change the outcome of conflict, we would expect to see substantial differences in magnitudes of the coefficients, particularly Red Communications and Blue Communications impacting positively or negatively the amount of territory gained by Red across 10 years. Most results are statistically significant to the 0.01 level, likely to the high total number of observations (N = 327,600, Prob F[8,327591] < 0.00, R^2 = 0.1380). Various residuals plots of some variables (Figure 6.4) and a Breusch-Pagan/Cook-Weisberg test, indicate non-constant variance (χ^2 = 38.82, P > 0.00), so robust standard errors are used in the regressions.

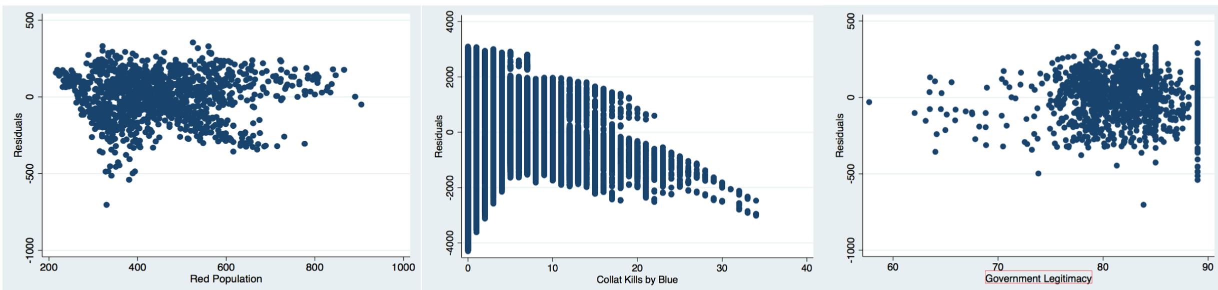


Figure 6.4 – Residuals Plots Indicate Non-Constant Variance

Table 6.4 – Red Territory Controlled Regression Table of Results

Variable DV **redcont** (Standardized) / **IV** (Standardized)	**CGW**				**4/5GW**			
		Rural Smooth	**Rural Rough**	**Urban**		**Rural Smooth**	**Rural Rough**	**Urban**
zredcollat	0.106***	13.6***	7.24	2.603***	0.174***	1.24***	1.15***	0.353***
zrzedcomm	0.087***	-0.009***	0.0805***	0.187***	0.238***	0.027***	-0.006***	-0.020***
zbluecollat	1.04***	0.023***	0.0321***	-0.159***	0.081***	0.024***	0.1004***	-0.040***
zbluecomm	-0.010	0.137	0.041	0.129***	0.212***	0.039***	-0.028***	-0.065***
zunempl	0.150***	-0.080***	0.0039***	0.0385***	0.276***	0.124***	0.1325***	0.098***
zgovtlegit	-0.103***	0.0077***	0.0049***	-0.071***	-0.179***	-0.218***	-0.159***	-0.090***
blueconv	-0.079***	-0.093***	0.0076***	-0.032***	-0.469***	0.478***	0.512***	-0.692***
bluepara	0.022***	0.0156**	0.0075**	0.051***				
constant	0.915***	9.43***	0.086***	1.07***	-0.496***	-0.182***	-0.129***	-0.781***
R^2	0.090	0.133	0.214	0.509	0.402	0.758	0.761	0.749

Overall, the models appear to be highly non-linear. R^2 is low in the CGW model and all three CGW terrain scenarios. Within the CGW model, it is best in the Urban scenario, at about 0.51. The fit appears better in the three 4/5GW terrain scenarios, about 0.75 to 0.76. But the overall R^2 for the 4/5GW model is unremarkable at 0.40.

As expected, an increase in the unemployment rate generally is associated with an increase in Red Territory, primarily through the recruitment mechanism. The exception is in the Classic Rural Smooth scenario. This could possibly be explained that Red forces are more exposed in smooth terrain and Blue has better mobility. Increased Government Legitimacy favors Blue (decrease in Red Territory, except in the Rural Smooth and Urban CGW scenarios, where the effect is almost negligible (standardized coefficient less than 0.01).

If 4/5GW communications increase the pace of a protracted insurgency, we would expect that the 4/5GW scenarios would show an increased effect on Red Territory Controlled when compared to the Classic scenarios. Indeed, increasing Red Communications capability in the 4/5GW scenario has more than double the effect on Red Territory Controlled when compared to the CGW scenario (0.238 versus 0.087, a 173% increase). Increasing Red Communications in both the CGW Smooth and 4/5GW Rough and Urban scenarios actually decreases Red Territory, probably because in the 4/5CGW scenarios, Blue has increased mobility over smooth terrain (including paradrops), and in urban areas (Blue reinforcements are spawned in urban terrain). An increase in Red Communications is associated with increases in Red Territory in both rough and urban terrain in the Classic scenarios.

More pertinent to this study, however, is that the coefficients of the IVs in the combined 4/5GW scenarios are close to double those of the Classic scenarios—increasing Red

Communications capabilities by one standard deviation appears to approximately double Red's territory gain in the 4/5GW model versus the CGW. Interestingly, increasing Blue Communications also increases Red Territory in both models, perhaps because Blue Territory is increased as well.

To test this, we regress Blue Territory Controlled as the dependent variable. The results are tabulated in Table 6.5, below.

Table 6.5 – Blue Territory Controlled Summary Table of Results

Variable DV zbluecont (Standardized) / **IV** (Standardized)	**CGW**	**Rural Smooth**	**Rural Rough**	**Urban**	**4/5GW**	**Rural Smooth**	**Rural Rough**	**Urban**
zredcollat	2.91***	2.02***	0.692***	-1.03***	0.325***	0.263***	0.249***	0.054***
zredcomm	0.0392*	0.023***	-0.002	-0.062***	-0.268***	-0.001	-0.002***	-0.0002
zbluecollat	-0.688***	0.194***	-0.005	-0.072***	0.024***	0.142***	0.147***	0.021***
zbluecomm	0.051**	0.052***	0.007	-0.084***	-0.199***	0.025***	0.006***	0.11***
zunempl	-0.119***	-0.022***	-0.031***	-0.098***	-0.230***	-0.046***	-0.051***	-0.143***
zgovtlegit	-0.006**	0.0089***	-0.014***	0.0337***	-0.108***	-0.012***	0.003**	-0.023***
blueconv	0.092***	0.151***	0.161***	0.0160***	0.973***	0.580***	0.592***	0.999***
bluepara	-0.0004	0.0053***	-0.004***	-0.033***	†	†	†	†
constant	1.083***	0.491***	-0.486***	0.331***	-0.188***	-0.948***	-0.948***	0.515***
R^2	0.147	0.207	0.240	0.509	0.539	0.554	0.549	0.502

Robust standard errors
*Significant to the 0.01 level
**Significant to the 0.05 level
***Significant to the 0.001 level
†Blue Paradrops included in 4/5GW model

Once again, R^2 displays similar characteristics when we regress the same independent variables on Blue territory. It is low in the CGW scenarios and higher in the 4/5GW scenarios. It is highest in the Urban scenarios of each model, and lowest in the overall models. It is lower in the 4/5GW scenario than when Red Territory is the dependent variable, dropping from about 0.76 in the individual scenarios to 0.50 to 0.55, similar to the best CGW scenario for the Red territory regression. This is likely a result of the non-linearity of the models.

Red Communications are not statistically significant in several scenarios in which Blue Territory is the dependent variable, although the variable is significant for Red Territory. This could be interpreted that an increase in Blue's Communications advantages both sides, but they advantage Blue in more scenarios. The ability of Blue to reinforce itself ("blueconv," of Blue Conversions) is significant, and appears to be two orders of magnitude more important in the 4/5GW scenarios than in the CGW scenarios (0.973 versus 0.092).

A comparison of the terrain scenarios for the combined CGW and 4/5GW models is shown Table 6.6, below. Rural scenarios present very similar results, regardless of smooth or rough terrain. This argues somewhat against Fearon and Latin's (2003) findings.

Table 6.6 - Red Territory Controlled Table of Results for Combined CGW-4/5GW

Variable **DV zredcont** (Standardized)	**Combined CGW-4/5GW**			
		Rural Smooth	**Rural Rough**	**Urban**
IV (Standardized)				
zredcollat	-0.0472***	0.729***	0.739***	0.386***
zredcomm	0.0104***	-0.194***	-0.192***	-0.185***
zbluecollat	0.0967***	0.016***	0.202***	-0.153***
zbluecomm	-0.0298***	-0.187***	-0.211***	-0.249***
zunempl	0.259***	0.141***	0.129***	0.210***
zgovtlegit	-0.107***	-0.181***	-0.191***	-0.120***
blueconv	-0.380***	-0.032***	0.068***	-0.419***
bluepara	-0.281***	-0.078***	-0.157***	-0.282***
constant	0.399***	0.803***	0.782***	-0.336***
R^2	0.138	0.222	0.345	0.448

But why would increasing Blue's capability help Red? One could argue that the faster pace and range of intelligence helps both sides. To check this, Blue Territory gain was regressed in the two models. But we find that this is NOT the case. An increase in Red Communications and Blue Communications both relate to a *decrease* in Blue Territory Controlled. Thus, the increased pace of the 4/5GW model appears to favor mainly the insurgents. Occupation of territory by Red and Blue forces across the 10 years of simulated time in the six terrain models is indicated in Figure 6.5, below. The two branches of the Blue territory in the 4/5GW model (labeled "5GW) show Blue territory gains with and without augmentation of government forces by a third-country force.

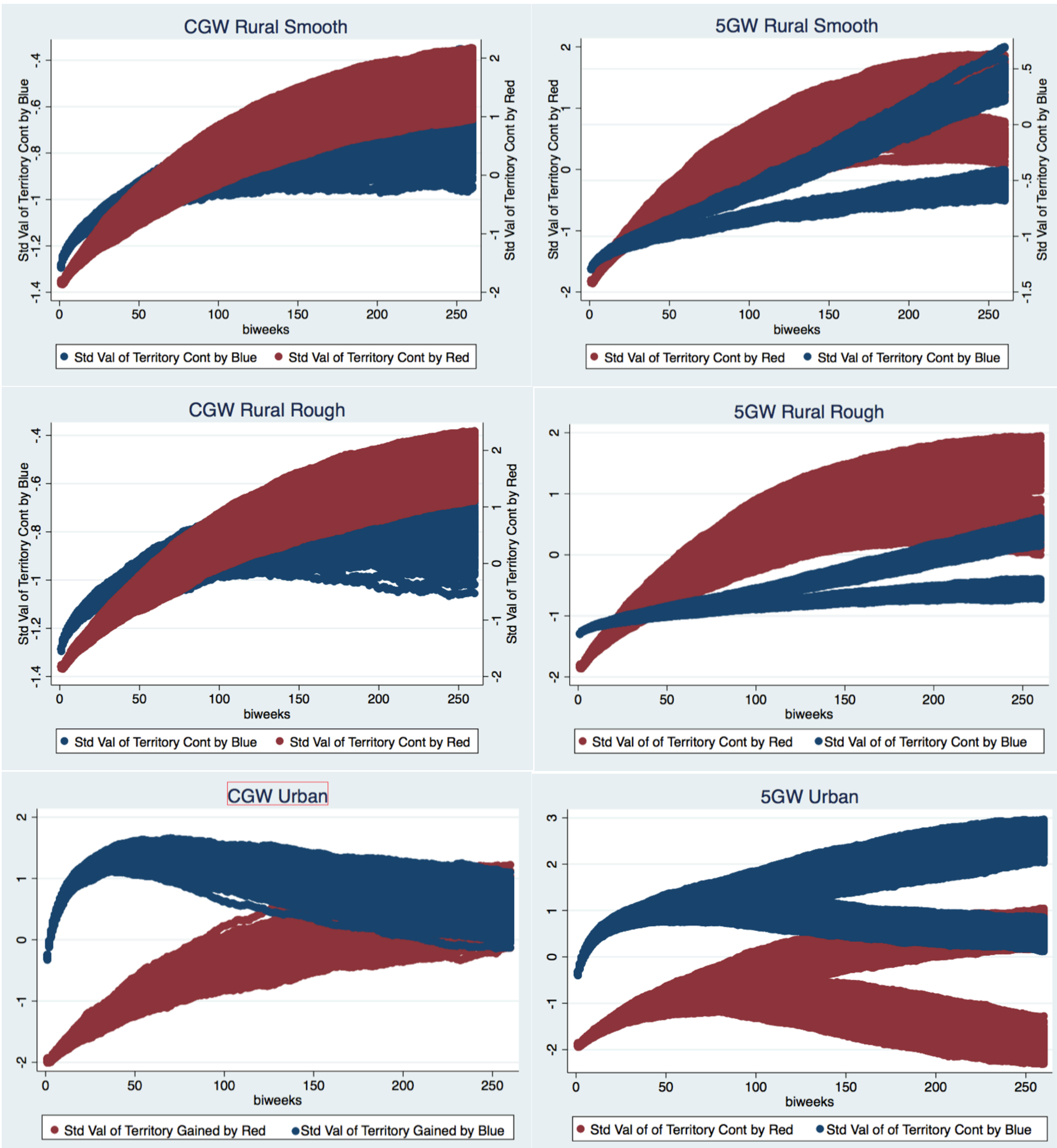


Figure 6.5 – Gain in Territory by Red and Blue Forces in Six Terrain Scenarios

Theory 2: Time to victory as the dependent variable.

Victory is defined as one side occupying 10 percent more territory and having 10 percent more combatants than the opponent. For the Combined CGW and 4/5GW case:

Pooled Linear regression (Robust Std. Errors)	Number of obs = 327,600 F(8, 327591) = 7360.45 Prob > F = 0.0000 R-squared = 0.2070 Root MSE = 61.647

Table 6.7 - Red Victory Time Regression for Combined CGW-4/5GW

DV Red Victory Time	Coef.	Robust Std. Err.	t	P>t
zredcollat	-3.55***	.2458673	-14.43	0.000
zbluecollat	7.63***	.2663827	28.66	0.000
zredcomm	-3.78***	.1270813	-29.74	0.000
zbluecomm	-4.07***	.1271363	-32.01	0.000
zunempl	20.6***	.1152857	178.98	0.000
zgovtlegit	-12.2***	.1628731	-75.04	0.000
blueconv	-35.0***	.2308167	-151.66	0.000
bluepara	-9.16***	.3173758	-28.86	0.000
constant	49.8***	.3042018	163.79	0.000

Pooled Linear regression (Robust Std. Errors)	Number of obs = 327,600 F(8, 327591) = 6522.05 Prob > F = 0.0000 R-squared = 0.2020 Root MSE = 50.628

Table 6.8 - Blue Victory Time Regression for Combined CGW-4/5GW

DV Blue Victory Time	Coef.	Robust Std. Err.	t	P>t
zredcollat	15.5***	.2624164	58.98	0.000
zbluecollat	2.73***	.2586985	10.54	0.000
zredcomm	-5.82***	.1225911	-47.44	0.000
zbluecomm	-4.56***	.1228051	-37.07	0.000
zunempl	-11.9***	.0795714	-149.11	0.000
zgovtlegit	-1.75***	.0859727	-20.29	0.000
blueconv	28.2***	.1906221	148.02	0.000
bluepara	9.57***	.1899836	50.35	0.000
_cons	5.64***	.1778195	31.75	0.000

***Significant to the 0.01 level

The CGW and 4/5GW scenarios are compared below:

Table 6.9 - Red Victory Time Regression

DV Red Victory Time in Bi-weeks	**CGW**				**4/5GW**			
		Rural Smooth	**Rural Rough**	**Urban**		**Rural Smooth**	**Rural Rough**	**Urban**
IV (Standardized)								
zredcollat	242.7***	840.2***	460.075	312.0***	1.68***	56.3***	59.4***	3.24***
zbluecollat	83.2***	100.7***	48.24***	42.6***	12.5***	18.1***	16.5***	7.42***
zredcomm	8.40***	-5.00*	9.53***	18.3***	4.14***	0.256	-0.551**	-1.02***
zbluecomm	8.61***	8.57***	-0.643	21.4***	4.87***	1.08***	-0.948***	0.702***
zunempl	13.8***	15.3***	7.87***	12.3***	16.4***	14.8***	15.6***	5.07***
zgovtlegit	-4.71***	-2.88***	-8.25***	-2.82***	-2.25***	8.16***	9.61***	1.96***
blueconv	-40.5***	-47.6***	-69.0***	-3.64***	-25.4***	-15.8***	-12.8***	-3.16***
bluepara	2.44***	0.246	3.25***	4.16***	†	†	†	†
constant	246.3***	620.8***	380.5***	238.0***	15.9***	26.5***	27.8	-.242

***Significant to the 0.01 level
†Software eliminated Blue Paradrops for collinearity in the 4/5GW Scenario

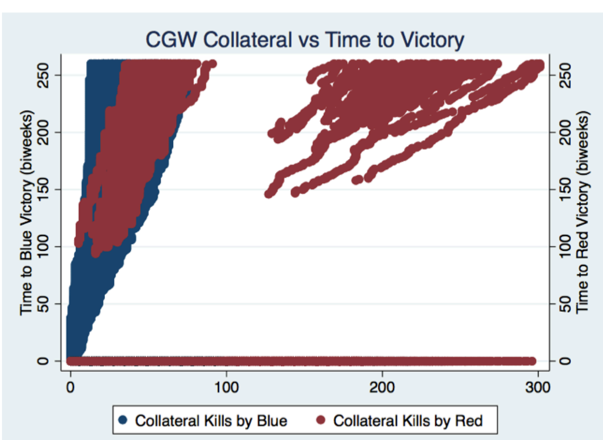


Figure 6.6 – Collateral Kills vs. Time to Blue Victory

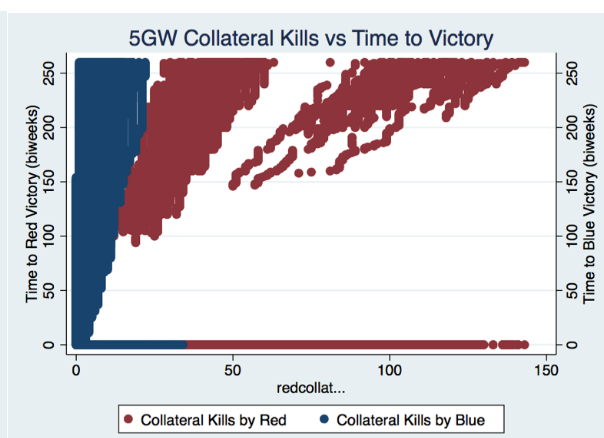


Figure 6.7 – Collateral Kills vs. Time to Red Victory

Collateral deaths show a strong effect in these models. Increasing collateral deaths are associated with lengthening Red victory time. In the Classic scenarios, one standard deviation in the collateral deaths caused by Red add on average 243 bi-weeks to time for Red Victory, while those caused by Blue add only about 83 bi-weeks. But in the 4/5GW scenarios, one standard deviation in Red Collateral deaths add only a little under 2 weeks, while the same increase in Blue collateral deaths add 18 weeks. Although that's less than a quarter of the time than in the Classic scenarios. This would indicate that, as expected, the pace of battle is more rapid in the 4/5GW model. However, additional collateral deaths caused by Red add fewer weeks than those caused by Blue in 4/5GW model, whereas they add more weeks to the conflict than Blue's collateral deaths in CGW. This might be explained by the fact that Red is already causing significant collateral deaths by suicide bombings in the CGW scenario.

As for communication, Blue and Red communications in the 4/5GW scenarios are associated with a decrease in Red's time to victory, both adding a little over 4 bi-weeks to victory time as compared to 8.4 and 8.6 bi-weeks respectively in the Classic scenarios. Again, 4/5GW Communications may favor both sides, but appear to favor the insurgents more so.

Theory 3: Faction Attaining Victory as a Categorical Dependent Variable

Another way of assessing the impact of 4/5GW communications on insurgency is to look at which faction attained victory at the end of the 10-year simulation period. Data were tabulated for the end of the 10-year period for each of the six scenarios. The Victory Condition was coded RED, BLUE, or STALEMATE, (same criteria as above). If RED or BLUE was in the Victory Condition (more than 10% territory occupied and more than 10% combatants than the opponent) at 260 bi-weeks, the variable was encoded accordingly. If neither side achieved victory at the end of 10 years, the condition was coded as STALEMATE.

Since a victory in this case is a categorical dependent variable, a multinomial logistic ("m-logit") regression was utilized, using Red Victory after 10 years as the dependent variable (an outcome of "1" means Red Victory after 260 turns is True).

Table 6.10 - Red Victory Log-Odds

Multinomial logistic regression			Number of obs		=	327,600
			Wald chi2(8)		=	54877.11
			Prob > chi2		=	0.0000
Log pseudolikelihood = -80315.278			Pseudo R2		=	0.3452
victoryred	**Coef.**	**Robust Std. Err.**	**z**	**P>z**		
0	(base outcome)					
1						
zredcollat	-0.0075192	0.0113334	-0.66	0.507		
zbluecollat	0.2610095	0.0105173	24.82	0.000		
zredcomm	-0.2166313	0.0079788	-27.15	0.000		
zbluecomm	-0.2931104	0.0080896	-36.23	0.000		
zunempl	1.416525	0.0084378	167.88	0.000		
zgovtlegit	-0.6315957	0.0068581	-92.10	0.000		
blueconv	-2.462725	0.0173047	-142.32	0.000		
bluepara	-0.4215201	0.0179182	-23.52	0.000		
_cons	-1.660187	0.0159236	-104.26	0.000		

Robust standard errors
*Significant to the 0.01 level
**Significant to the 0.05 level
***Significant to the 0.001 level
†Some observations completely determined due to indicated variable, standard errors questionable
††Blue Paradrops included in 4/5GW model

For the combined models, an increase of one standard deviation of Red or Blue Communications capabilities decreases the log-odds of Blue Victory by about 27-28 percentage points. And for the Stalemate condition, improvement of one standard deviation in Red or Blue Communications capability increases the log-odds of Stalemate by about 30 percentage points. Both results are statistically significant to the 0.01 level.

Table 6.11 – Red Victory Log-Odds Coefficients by Scenario

Categorical DV Red Victory	**CGW**				**4/5GW**			
		Rural Smooth	**Rural Rough**	**Urban**		**Rural Smooth**	**Rural Rough**	**Urban**
IV (Standardized)								
zredcollat	8.73***	37.7***	33.9***	14.4***	1.13***	7.95***	6.71***	1.25***
zbluecollat	2.26***	1.56***	2.45***	3.217***	0.088***	-0.202***	0.303***	0.712***
zredcomm	0.479***	-0.768***	0.616***	0.406***	0.426***	0.319***	0.039	-0.456***
zbluecomm	0.150	-0.016	-0.838***	-0.0395	0.362***	.308***	-0.335***	-0.084**
zunempl	0.951***	1.27***	0.644***	1.40***	2.44***	4.78***	3.77***	†
zgovtlegit	-0.298***	-0.646***	-0.555***	-0.561***	-1.15***	-1.61***	-0.565***	-0.612***
blueconv	-2.75***	-8.99***	-9.21***	-0.021	†	†	†	†
bluepara	0.111***	-0.058*	0.275***	0.119***	††	††	††	††
constant	5.22***	21.9***	21.1***	-0.500***	-6.32***	-11.2***	-8.21***	-9.70***

When we compare the CGW and 4/5GW models with the three victory conditions, we would expect that the 4/5GW model would show a decrease in the log-odds of Red Victory after 10 years, and an increase in the log-odds of Blue Victory or Stalemate. Table 6.12 presents a summary of the regression for Red, Blue, and Stalemate Victory Conditions for the two models. It appears that there is little difference in the log-odds of Red Victory in the two models from the Red Communications variable (0.479 and 0.426 for CGW and 4/5GW, respectively). There is about double the effect of increasing Blue Communications by one standard deviation on the log-odds of Red Victory in the 4/5GW model (0.362) versus the CGW model (0.15).

Table 6.12 – Summary of Victory Coefficients by Model Type

	Red Victory at 260 Bi-weeks		Blue Victory at 260 Bi-weeks		Stalemate at 260 Bi-weeks	
	CGW	4/5GW	CGW	4/5GW	CGW	4/5GW
zredcollat	8.73***	1.13***	-0.626***	-0.047***	-5.41***	-0.073***
zbluecollat	2.26***	0.088***	-2.79***	-0.367***	-1.20***	0.062***
zredcomm	0.479***	0.426***	-0.012	-1.03***	-0.172***	-0.627***
zbluecomm	0.150	0.362***	0.050	-1.09***	-0.211***	-0.653***
zunempl	0.951***	2.44***	-0.337***	-0.778***	-0.145***	-0.075***
zgovtlegit	-0.298***	-1.15***	0.117***	-0.469***	0.024***	-0.453***
blueconv	-2.75***	†	-0.001	1.48***	1.021***	0.392***
bluepara	0.111***	††	-0.042***	††	-0.026**	††
constant	5.22***	-6.32***	-3.43***	-0.288***	-3.75***	0.237***

Multinominal Logistic Regression – coefficients in log-odds
*Significant to the 0.01 level
**Significant to the 0.05 level
***Significant to the 0.001 level
†Some observations completely determined due to the indicated variable, standard errors questionable
††Blue Paradrops included in 4/5GW model, eliminated by software for collinearity

For the Blue Victory condition, Red and Blue Communications appear to have a more dramatic effect, is significant, and is about two orders of magnitude (–1.03 and –1.09) above the CGW scenario (–0.012 and 0.50), where the effects are not significant. They also have the reverse of the expected sign, and an increase by one standard deviation is associated with a decrease in the log-odds of Blue Victory by about 109 percentage points. Interestingly, increases in Red and Blue Communications also appear to decrease the log-odds of a Stalemate condition by 63 and 65 percentage points, respectively, with Blue apparently the recipient of much of the advantage. So Red and Blue Communications would appear to make no difference to Red Victory, while an increase in Red and Blue Communications actually decreases the log-odds of Blue Victory and Stalemate in the 4/5GW model compared to the CGW model. This result is possibly explained by measuring the result at the end of 10 years, while the previous analysis looked at the earliest bi-week by which the victor attained a 60% advantage in troops and territory.

Discussion of Results

Analysis of the models was undertaken to determine if there are quantitative differences between the classic guerrilla warfare model (simulating insurgent warfare as practiced up to the mid-twentieth century) and so-called Fourth or Fifth Generation Warfare (modern insurgent warfare, using internet, social media, and twenty-first century communications). The key variables for comparison of the two models were communications in the combat subroutine, and government legitimacy, varied in the government legitimacy subroutine. Communications operates to improve the speed and accuracy of tactical intelligence and was expected to improve battle performance. Government legitimacy is affected by collateral damage, and was expected to impact recruitment, with decreases in legitimacy raising Red recruitment, and increases in legitimacy lowering Red recruitment and bolstering Blue recruitment.

Three measures of merit, exemplified by different dependent variables, were chosen to evaluate the differences. First, would modern warfare advantage one side or the other in terms of *territory gained*, as compared to classic guerrilla warfare? Second, would the *time* to "victory"—a state of advantage for one side or the other, however defined—be shortened by modern methods of warfare versus the protracted nature (as Mao defined it), of classical insurgency. Finally, would the two different models of warfare yield a difference in the *identity of the victor*, insurgent or government, after a set period of time? The preceding analysis offers some insights, but also raises additional questions as to the differences between the two models of insurgent warfare.

The results of the regressions of Territory Gained gave mixed results. Although increasing both Red and Blue Communications in the 4/5GW model approximately doubled Red's territory gained compared to the CGW model, Blue Territory regressed on Blue Communications increased both Red and Blue territory gains in the 4/5GW model. Here, Red Communications were not statistically significant. The ability of Blue to convert more supporters overshadowed the effect of Blue Communications. The type of the terrain in the model (rural rough or smooth, or urban) appeared to produce quite different results with respect to Red Territory gained. The overall effect of Red Communications was associated with an increase Red Territory, while Blue Communications were associated with a decrease, indicating that the model was working correctly. The type of battle terrain seemed to make little difference in the relation of Red Communications with Red Terrain, but urban terrain clearly favored Blue, being associated with a larger decrease in Red Territory. Government legitimacy seemed as an overall negative to Red Territory gains, and as expected, legitimacy seemed to have slightly more power associated with rural battlefields compared to urban.

Number of bi-weeks to victory condition produced indicators more in accordance with theory. The impact of both Red and Blue Communications in the 4/5GW model was significant and about double that in the CGW model (4.1 and 4.9 versus 8.4 and 8.6), indicating that a substantial decrease in number of bi-weeks to Red Victory was associated with 21st century communications. However, collateral damage (civilian deaths) appeared to have an order of magnitude impact higher than communications. Increasing both Red and Blue Communications appears associated with a decrease in time to Blue Victory as well, which is slightly stronger than Red's time to victory (–5.8 and –4.6 for Red and Blue Communications, respectively, on Blue time to victory gained versus –3.8 and –4.7 for Red time to victory). Government legitimacy, unemployment, and blue conversions all have signs in the correct direction and are significant.

Like territory gained, the results of using Victory Condition after 10 years as the dependent variable were mixed. There was little difference in the log-odds of Red Victory for the two models associated with Red Communications, and Blue Communications were not significant in the CGW model. However, Blue Communications appeared to be associated with an *increase* in the log-odds of Red Victory in the 4/5GW model. Thus, this regression would indicate that the advantage to victory from Red Communications is almost the same in both models (0.48 and 0.43 for CGW and 4/5GW, respectively), and Blue Communications increases the log-odds of Red Victory after 10 years in 4/5GW. Furthermore, an increase in Red Communications decreases the log-odds of Blue Victory after 10 years in 4/5GW compared to CGW. Conversely, Blue Communications is significant and reverse of the expected sign for Blue Victory after 10 years. An increase of one standard deviation in Blue Communications appears to *decrease* the log-odds of Blue Victory by about 109 percentage points. Finally, an increase of one standard deviation in

Blue Communications is also associated with a decrease in the log-odds of stalemate after 10 years. Again, both of these results seemed to favor the rebel side.

Thus, while the effects of the key input variables of Communications and Government Legitimacy operated in the expected direction in both the CGW and the 4/5GW model, the effects generally seemed to favor the rebels in both models. In fact, increasing Red Communications was had about the same effect in the CGW and 4/5GW model with respect to the chance of Red victory, but had a much stronger effect in decreasing the chances of Blue victory and Stalemate in the 4/5GW model than the CGW model. Blue communications seemed to decrease the chance of both Blue victory and stalemate as well in 4/5GW, indicating that 21st century communications may empower insurgents more than government forces.

Strangely, increasing government legitimacy appears to actually decrease the chances of Blue victory and stalemate in 4/5GW compared to CGW. However, it is associated with a stronger decrease in Red victory in 4/5GW than in CGW, which is expected. This result should be examined in more depth in future research.

Chapter 7 – Conclusions

Military theorists have been using the concepts of Fourth Generation Warfare since the last decade of the 20th century to describe changes in the strategy of warfare. Its logical extension, Fifth Generation Warfare, while not as widely accepted, was added by some authors to describe all means—strategic, operational, and tactical—of conducting warfare utilizing all instruments of power—military and non-military—to attack the warfighting capabilities and will of an enemy. But concepts of Fourth or Fifth Generation Warfare have lacked precise definition and intellectual rigor.

Two agent-based models of guerrilla warfare, one simulating classic guerrilla warfare (CGW) and the other simulating features of Fourth and irregular Fifth Generation Warfare, were developed and then and run repeatedly in the context of three simulated physical environments (urban terrain, rough rural terrain, and smooth rural terrain). Values of several independent variables were systematically varied to generate contrasting emergent behavior. The two models were then analyzed to compare the impact of 4/5GW capabilities—primarily internet-age communications—on three dependent variables: territory gained, time to victory, and the identity of the victor (government or rebel). The models functioned generally as expected. However, the non-linearity of the micro-behavioral approach of agent-based models occasionally generated some unexpected outcomes.

Theory 1, Territory Gained: As expected, increasing Red communications capability in the 4/5GW scenario overall increased Red Territory Controlled as compared to the CGW scenario. In fact, increasing Red Communications by one standard deviation was associated with approximately doubling Red's territory gain in the 4/5GW model versus the CGW model. However, increasing Blue Communications also increased Red Territory gained in both models. This could be interpreted that an overall increase in communications capabilities leads to more aggressive tactics and more engagements for both sides. In the 4/5GW scenarios, Blue has increased air mobility across rough terrain and in urban areas. However, when Blue territory gain was regressed on communications, it showed that an increase in Red Communications and Blue Communications both were associated with a decrease in Blue Territory Controlled in the 4/5GW model. Thus, the increased rate of engagements of the 4/5GW model appeared to favor only the insurgents. Blue gains were not increased in the 4/5GW model, which simulated increased lethality of Blue forces, or higher collateral damage created by Red's suicide bomb attacks. Rather, this result was consistent with counterinsurgency theory (Army, 2006), which holds that more aggressive tactics on the government side often lead to counterproductive results. Increases in the pace and violence of counter-insurgency operations can increase alienation of the population through killing of innocents and destruction of sources of livelihood, thus turning broad public support toward the rebels and increasing the likelihood of insurgent victory.

Theory 2, Time to Victory as the dependent variable: Victory is defined as one side occupying 10 percent more territory and having 10 percent more combatants than the opponent. Here, we see that both Red and Blue communications in the 4/5GW scenarios are associated with a decrease in Red and Blue time to victory, respectively, indicating that the pace of engagements is accelerated in the 4/5GW scenarios as expected. Collateral deaths also show strong effects in these models, lengthening time to victory in all scenarios, but less so in the 4/5GW scenario.

Taken together, these results appear to indicate that 4/5GW Communications are associated with an accelerated pace of war, shortening time to victory for either side.

Theory 3, Identity of the Victor: Similar to the results of territory gained, results using Victory Condition after 10 years as the dependent variable were mixed. There was little difference in the log-odds of Red Victory for the two models associated with Red Communications, and Blue Communications were not significant in the CGW model. However, Blue Communications appeared to be associated with an increase in the log-odds of Red Victory in the 4/5GW model. Furthermore, an increase in Red Communications decreases the log-odds of Blue Victory after 10 years in 4/5GW compared to CGW. Conversely, Blue Communications is significant, but the coefficient has the inverse of the expected sign for Blue Victory after 10 years One would expect log odds of Blue victory to increase with better Blue Communications, but the reverse is true in the results. An increase in Blue Communications appears to *decrease* the log-odds of Blue Victory. Finally, an increase in Blue Communications is associated with a decrease in the log-odds of stalemate after 10 years. These results could indicate either a flaw in the model, or it could indicate increased leverage for Red when communications is improved for all.

As in Theory 1, the results for Theory 3 could also be consistent with counterinsurgency theory. On the other hand, the results could also indicate that the recruitment model or collateral damage variable is too sensitive to Blue actions and that the simulation requires further adjustment. Additionally, constraints in the model programing, such as Blue forces spawning in the cities and on roads, artificialities in movement of the agents, or using unemployment and government legitimacy as proxies for other variables, might have affected the model in unforeseen ways.

Future versions of the model should take lessons learned from this research and apply it to refining the model design. In particular, future studies should focus on better understanding detailed mechanisms of internet communications that appear to offer advantage to Red at the expense of Blue. Also, direct simulations of poverty and government political power and capacity could be included to more tightly align the models with theories of civil violence and stabilization, and improve the model performance in scenarios with foreign military assistance.

The question of whether 4GW and irregular 5GW are revolutions or evolutions of CGW has not been resolved by this investigation. The results generally favored the rebels in both CGW and 4/5GW scenarios. The addition of 21st century information technologies seemed to change this overall dynamic in specific cases, and usually only marginally. In fact, a determined insurgency, fighting on its home territory against a government that lacks enough popular support to resist the nation falling into rebellion in the first place can often garner local and regional support to outlast government efforts to eliminate them, as well as leverage available technologies and methods to effectively counter those of its enemy.

This research project was purposefully designed so that the 4/5GW capabilities would be additions to a basic model of guerrilla warfare. Therefore, there is danger that these additions were simply insufficient in modeling the true extent of the differences between the two concepts of war, and that 4/5GW is, in fact, revolutionary. Further research, perhaps using a different approach that models 4/5GW and CGW as their own unique simulations, or that use an altogether different approach and method, may be required to answer this question conclusively.

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