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# MODELING STRATEGIC EFFECTS IN WARGAMES

by

David M. Whittemore, Major, USAF

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Advisor: Mr. Matt Caffrey

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## Disclaimer

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## *Preface*

I once worked at Air Combat Command (ACC) headquarters helping to put together its fiscal year 2000 budget request (FY00 POM). We tried to use computer models and simulations to optimize our funding decisions and understand the impacts of our shortfalls. We wanted to know, for example, should ACC focus on upgrading its weapons, or the infrastructure for supplying and sustaining those weapons? If we can't afford both, what's the impact of choosing one over the other on our ability to fly, fight and win? We asked our analysis/wargaming people to help answer these types of questions, but even with their state of the art equipment, they simply didn't have the tools to provide good answers.

Advances in computers and information management have placed us in the middle of a revolution in military affairs. Computer-based wargames, with their tremendous data processing capabilities, should be at the center of this revolution, crunching the numbers and helping us understand the complicated business of war. The problem is that war is about people. To understand war you have to understand how people think. This paper is about strategic effects; it is about wargames; but most of all it is about the thought processes behind the strategic decisions. Special thanks to the Major Kevin Cole, Air Force Doctrine Center, and Matt Caffrey, Air Command and Staff College, without whose assistance this paper would not be possible.

## *Abstract*

This paper addresses how strategic effects win and lose wars. Strategic effects are defined here as the impacts that the outcomes from wartime operational and tactical events have on the highest level of decision-makers. Building on concepts proposed by Thomas Schelling, Robert Pape and John Warden, it proposes a model .that can be incorporated into the artificial intelligence routines of a computer-based strategic wargame to simulate the goals and will of either or both sides in a conflict. This proposed model is called the value-based strategic effects model (VBSEM). VBSEM essentially provides rules for determining the value of each side in a conflict and then has each side behave according to economic and risk management formulas relative to actual and potential changes in that value. The underlying assumption is each side will ultimately act in its own best interest (as they define their best interest) based on the information available. This paper looks at symmetrical and asymmetrical strategic effects. Finally it offers advice on how VBSEM can be incorporated in a computer-based strategic wargame.

## Chapter 1

# Introduction

*Although the process of warfare is still clouded by obscurity and confused by myths, sense can be made of it nevertheless.*

— James F. Dunnigan, author of *How to Make War*

Strategic effects are the impacts that the outcomes from wartime operational and tactical events have on the highest level decision-makers. A specific strategic environment exists at the outbreak of war in which both sides engaged in conflict are the key players. Operational and tactical events, such as invasions and urban bombings, create outcomes which change the strategic environment. These outcomes become strategic effects when they carry important meaning to primary decision-makers. Meaning is the key word here. Different people may view a single outcome differently, and consequently react differently. What causes one national leader to feel compelled to impose his will on another? What convinces another to continue to fight to the bitter end rather than yield? Is there a better way to understand meaning in terms of how national leaders need to think in order to do their jobs? An artificial intelligence programmer once said the problem with people is they are much better at expressing *what* they think than they are at explaining *how* they think.[i] Is it possible to understand the calculus of the person-in-charge? If so, can this calculus be incorporated into a wargame?

JCS Pub 1-02 defines wargames as “a simulation, by whatever means, of a military operation involving two or more opposing forces, using rules, data, and procedures designed to depict an actual or assumed real-life situation.”[ii] Wargames are great tools for helping one understand war without the drawbacks of learning through actual experience. Wargames are especially good at simulating physical interactions between military machines. The student of war can theorize how one weapon system will fare against another, and the wargame can test it. Wargames are also good at understanding some of the more human aspects of war. Opposing players using similar weapon systems can develop strategies for achieving desired outcomes at the other’s expense. Nor do wargames need two players to achieve this benefit. Some wargames allow a single person to play “against the computer.” In this case the wargame not only models the physical science of military machine against military machines, but the psychology of a human using strategy against strategy. Wargames are very good when they deal with something their programmers understand well, like the physical sciences. They are not as good when dealing with something less well understood, like the thinking of a person.

Fidelity is the degree of realism demonstrated by the wargame. Wargames tend to be most realistic when they focus on the physical processes of war rather than the psychological. Tactical wargames focus somewhat less on human factors than on those aspects of war “where the rubber meets the road,” and so tend to be very realistic. Operational (campaign) wargames deal not only with multiple, simultaneous tactical interactions, but they also introduce an almost equal amount of strategy (psychology) in the person of the opposing force commander (real or simulated). Though it is true a doctrinally and culturally representative opposing force commander would improve overall fidelity, the operational wargame does not require it since it still is primarily about the interaction of physical force. Strategic wargames, however, are ultimately much more about strategy (psychology) than physical science. In strategic wargames, the decision-making process holds center stage, not the dynamics of the battlefield. This means strategic wargames have a built-in fidelity obstacle to overcome: they have to model and simulate processes that are less well understood than those of tactical or operational wargames.

One way around this problem in a strategic wargame is to have a knowledgeable person play the role of opposition leader. This person may be an acknowledged expert in the politics and culture of the opposition country. Theoretically this person's expertise provides the necessary realism against which the friendly side practices its decision-making processes. This arrangement works fine when the focus of the strategic wargame is simply to practice making and coordinating decisions, but it does not help in understanding why the enemy made the decisions it did. People are good at saying what they think but not why they think it. Without knowing why a person chooses certain courses of action, how is it possible to predict the likely outcome of achieving our objectives (tactical and operational)? If it is possible to understand why a person chose a certain course, can that calculus be modeled in a computer? Letting a computer play the opposition leader has obvious benefits, such as fewer players needed; reproducibility; consistency. The key is creating a decision-making model for the strategic wargame to use that mirrors reality acceptably well.

This is where strategic effects come back into the equation. At the strategic level, operational and tactical outcomes, like defeated armies and bombed cities, are the inputs;

decisions, like surrender or defend to the last man, are the outcomes; and strategic effects (psychological impacts, cost-benefit analysis, political considerations, and so on) are the mechanisms which convert inputs into outputs. A strategic effects model then is what the computer needs to simulate the most essential part of the decision-making process. Why not just assume the opposing leader's knowledge of a particular bridge being destroyed, an important electrical power plant being out of commission, or his army being routed is sufficient to convince him to yield? Answer is it doesn't always work that way. In the Vietnam War, the US destroyed many more enemy bridges, power plants and soldiers than did the North Vietnamese, yet the US ultimately lost the war. Wars are not always fought symmetrically, with force-against-force. Sometimes they are fought asymmetrically, with each side pitting its strength against the other's weakness. In Vietnam, air power was an overwhelming US strength, yet the political will to use all that strength was lacking. North Vietnam asymmetrically attacked US political will and won its strategic objective. To be valid, the strategic effects model has to take into account symmetrical and asymmetrical strengths and weaknesses.

The application for the USAF is obvious: a valid strategic wargame model would help planners understand how conventional aerial bombardment can best be used to help win wars. It could help identify which targets are most likely to influence a leader to accommodate, and which targets are a waste of time. Such a wargame would help military decision-makers choose the best course of action for the forces available. Such a wargame could limit the destructiveness of war and help lay the foundation for a better state of peace.

Finally, a word about the boundaries of this paper. This paper is mostly about computer modeling and one aspect of strategic wargames—strategic effects. No attempt is made to discuss artificial intelligence in depth. No attempt is made to discuss strategic wargames in depth. No attempt is made to replace anyone's theory of war with a new one. Rather this paper attempts to use a few ideas from all three areas to answer its basic question of how can a computer can effectively model strategic effects in war. This paper will provide its answer based on three theories identified in Chapter 2, a proposed theoretical model in Chapter 3, and a partial mechanizing of that model in Chapter 4. The first step is to identify the theoretical foundation for the proposed model which this paper will call the Value-Based Strategic Effect Model (VBSEM).

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[i] Herbert Schildt, Artificial Intelligence Using C (Berkeley, CA: Osborne McGraw-Hill, 1987), 7.

[ii] Joint Pub 1-02. *Department of Defense Dictionary of Millitary and Associated Terms*, 23 March 1994, 459.

## Chapter 2

# Theoretical Foundation for a Strategic Effects Model

*"The facts will eventually test all our theories, and they form, after all, the only impartial jury to which we can appeal"*

—Jean Agassiz, author of Geological Sketches (1870)

Wargames don't reflect reality so much as they model our understanding of reality. A strategic wargame requires two things: 1) a good understanding of decision-making processes; and 2) a means for quantifying them. The following two chapters deal primarily with quantifying reality. This chapter deals strictly with understanding it. Specifically this chapter will review the relevant strategic effect aspects contained in the theories of Thomas Schelling, Robert Pape, and John Warden. The goal is to find common ideas useful to the development of a strategic effects model. One important caveat before starting. Due to space constraints the views of Schelling, Pape, and Warden are greatly condensed and filtered in order to fit into this paper. The author assumes responsibility for the degree of accuracy with which their theories are presented.

## Thomas Schelling and *Arms and Influence*

Schelling wrote this book thirty–three years ago and it still frequently quoted for its ideas on how military force can be used (or not used) to achieve desired strategic objectives. Influence rather than destruction for destruction's sake is the essence of Schelling. He used the word "compellence" to describe convincing one's wartime opponent to change switch from adversarial behavior to that of accommodation.[i] Other writers use the term coercion to mean the same thing.[ii] Regardless of the term used, Schelling showed that frequently the best way to win is to threaten more than you deliver and deliver only what is required to threaten credibly.

Threatening works when military force is viewed by one's opponent as a source of "pain" which can only be stopped through yielding. The secret then is to use just enough military power (or any other instrument of power) to hurt the opponent and make threats credible. If the opponent doesn't yield, one increases the pain through somewhat increased force and threats of even greater pain. This pattern continues until the opponent decides to yield. It is yield or be punished which is why at least one other writer has since dubbed this "punishment theory."[iii]

Punishment theory then requires two things: knowledge of what causes the opponent pain (what it values), and the force to inflict that punishment in a graduated way. Pain, as in a reaction to the loss of something of value, is a key part of a strategic effects model. It is a waste to use military force to "repel and expel, penetrate and occupy, seize, exterminate, disarm and disable, confine, deny access, and directly frustrate intrusion or attack;" unless those actions directly threaten whatever it is the opponent values.[iv] "To exploit a capacity for hurting and inflicting damage one needs to know what an adversary treasures and what scares him and one needs the adversary to understand what behavior of his will cause the violence to be inflicted and what will cause it to be withheld."[v] So what does the opponent value? This is an important question because what a state values most becomes its strategic Achilles heel.

Schelling thought state leaders valued the lives of their population most. To him, the credible threat of killing large numbers of civilians creates the necessary conditions to compel an opponent to yield. Survival potential, perhaps expressed in terms of casualties or life-span, is his the measure of merit for determining strategic effect. If the tactical and operational outcomes are causing massive casualties and a reduced survival rate, and the trend is likely to continue unless the opponent surrenders, then the strategic effect is simple. An opponent can be expected to accommodate once it becomes clear the friendly side has the means, ability and will to kill large numbers of the opponent's people.

A strategic effects model can quantify survival rate and potential threat to survival in a number of ways. Key variables might include casualties to-date, life-expectancy, reserve offensive lethality, reserve defensive effectiveness, willingness to exterminate, and civilian vulnerability. Using punishment theory as a guide, whichever side first achieves the means/ability/will to exterminate the other can be said to have "won" the war. In certain strategic environments, punishment theory works well. The problem is there are many other strategic environments where it doesn't work so well. What about totalitarian states which don't care about the welfare of their people except for the few who control political power?

Schelling's other major contribution to a strategic effects model is the impact of time as a pain multiplier. For example, societies have been able to annihilate each other long before the advent of nuclear weapons. What makes nuclear weapons so horrifying is the fact that their annihilation occurs in a matter of hours with no time to think, no time for reflection, no time for passions to cool, and no time for the destruction to end before it reaches its conclusion.[vi] Time is an important psychological component of war. Strategic effects occurring, and/or threatening to occur, within a compressed time period magnifies their psychological impact on decision-makers. It is the difference between a strategic effect of 90% casualties within the next 8 *hours* unless the opponent surrenders versus 90% casualties over the next 8 *years* unless the opponent surrenders.

Schelling's twin contributions of value and time set the stage, but are not enough alone. The next theorist took a hard look at thirty-three strategic air campaigns in the 20th century and found a strategic effect mechanism that was applicable across a much larger range of situations.

## Robert Pape and *Bombing to Win*

Pape argues that for coercive (compellence) purposes, the most important strategic effect mechanism is the opponent's cost-benefit analysis, especially as it relates to the "military ability to achieve its territorial or other political objectives."[vii] In other words, the opponent is willing to pay a price to get something of value provided the benefits outweigh the costs. The key mechanism for realizing those benefits at an acceptable cost is relative military power. The opponent embarks on a war strategy believing it has sufficient military power to achieve its objectives. Once it determines that it cannot achieve those objectives, and/or the projected costs are becoming too great, then the opponent is strongly motivated to "cut his losses." Pape calls this denial theory.[viii] Here strategic effects deal with the availability of sufficient military resources to achieve the objective.

Adding some complexity to this equation is the cost associated with surrender. Frequently this means the opponent loses political power and may even mean getting tried as a war criminal. The opponent will weigh the costs of continuing to fight against those of accommodation and will chose the option which costs least. Strategic effects then becomes a two part problem of relating operational outcomes associated with fighting against those associated with surrendering. The bottom line with denial theory is it requires the “ability to undermine the target state’s confidence in its own military strategy…Once a state is persuaded that objectives cannot be achieved, levels of costs that were bearable as long as there was a chance of success become intolerable. The target then concedes in order to avoid suffering further losses to no purpose.” [ix]

In punishment theory the strategic effect measure of merit is degree of threat to population’s survival. In denial theory, the measure of merit is the level of attrition achieved against that part of the opponent’s military force needed to achieve the desired objective. Like survivability, military force is a relatively easy variable to quantify.

A strategic effect model can capture the denial strategic effects by using a basic cost-benefit analysis model: Benefits of the desired objective (B) * Probability of achieving those benefits [p(B)] minus Costs, both military and political (C) * Probability of achieving those costs [p(C)] must be greater than zero.

$$B^*(pB) - C^*(pC) > 0$$

**Figure 1. Cost Benefit formula**[x]

Whoever first reaches a solution of less than or equal to zero will have incentive to end the conflict. An added benefit of this formula is the fact it doesn't need perfect cost or benefit information. The probabilities are the key variables. Even if both cost and benefit equal 1, a low probability of achieving an objective minus a high probability of incurring cost can capture the denial strategic effect of coercion. The side losing the requisite amount of military effectiveness first loses the war.

The problem with denial theory is it focuses too much on force-on-force military operations. Benefits and costs should certainly be a big part of a strategic effects model, but what about the root causes of war? Just because an opponent is forced to give up on its original strategy doesn't mean it won't try again with another strategy once it is strong enough. This situation occurred between World War I and World War II with Germany, and it could be happening now with Iraq. Where does the cost-benefit model fit with regards to the economic, diplomatic, political, moral, and cultural aspects of war? Don't these areas count? The next theorist argues they do but within the framework of the opponent operating as a system.

## John Warden and "Success in Modern War"

John Warden views the opponent as a system converting inputs into outputs. The inputs can include many things, but the output is survival.[xi] For this discussion the system will be the state. The state is made up of five elements, or rings, which are related hierarchically. The five rings consist of population, fielded forces, infrastructure, key production/energy conversion, and leadership.[xii]


**Figure 2. Warden's Five Rings**

Consistent with Schelling, the state has people as its core element, though in the fourth ring. Consistent with Pape, the state has a military for providing security for its people, though in the fifth ring. What's more important than population and fielded forces to the state's survival? One step up in the third ring is the infrastructure for helping people work more efficiently; that is,roads, bridges, schools, factories, legal institutions, banks, et cetera. Key production are the energy sources the state needs to make everything work smoothly—hydro, electrical, carbon-based fuel, and so forth. Providing the guidance to make all this work smoothly in the first ring is the state leadership. The more important the element, the less damage it can sustain before the state stops producing its own survival. Related to compellence and cost-benefit analysis, an opponent state must sue for peace once it recognizes a credible threat to one or more of these rings, or risk ceasing to exist as a state. Different from punishment and denial, Warden's theory allows strategic effects to occur in outcomes dealing with events other than just attrition of population or fielded forces.

The real benefit of Five Ring Theory is it begins to capture the synergy inherent within a state and the cascading effects that occur when one piece needed to achieve that synergism is removed. All the pieces are interrelated according to weighted their values. For example a Five Ring strategic effects model wouldn't say a 10% decrease in a state's leadership effectiveness would bring the opponent 10% closer to yielding. Rather it would say something like a 10% decrease in a state's leadership effectiveness also decreases the state's ability to produce/use energy efficiently (perhaps a 10% decrease), which in turn might reduce infrastructure effectiveness (another 10% decrease), which perhaps makes providing food and medicine more difficult (yet another 10% decrease), to add to a decrease in centralized military command (a 10% or greater decrease in operational effectiveness)—all of which makes a 10 decrease in leadership effectiveness add up to a strategic effect of the opponent being 50% closer to accommodation.

Does this accurately model reality? A definitive answer based on clear historical data doesn't exist. Only recently has conventional technology given states the capability to seriously threaten elements within a state other than just the military or general population. Current United States Joint doctrine, however, does seem to suggest desirable strategic effects can sometimes be achieved without totally destroying military forces or threatening the general population .

Warden also describes a type of strategic effect called "strategic paralysis."[xiii] Strategic paralysis is the outcome of a series of operational events known as parallel warfare. Similar to Schelling's time compression, parallel warfare describes large-scale, near-simultaneous destruction of targets. It is different in that the goal of parallel warfare isn't to make threats appear more terrifying. Rather the goal is to overload the opponent's leadership with so many simultaneous problems to solve, it can't decide which problem to address first. This causes the victim leadership to become overwhelmed, to lose control of events, and consequently to see only one way to regain at least some control--accommodate.

While useful, there are three problems with all three theories. First, they all focus on the use of overwhelming military force, such as the United States could employ if not limited by economic, political, or moral issues. The fact these factors could limit military force leads to the second problem. None of these theories explains asymmetrical strategic effects well. Asymmetrical strategic effects are positive outcomes in one area that are offset by negative outcomes in another. For example, in Vietnam, the US had overwhelming military power yet lost the war due to decreasing political support at home. How was North Vietnam able to turn the militarily disastrous Tet Offensive into a decisive strategic victory? This is a fundamental question not easily answered by any of the preceding theories. Failure to account for asymmetrical strategic effects leaves the strategic wargame extremely vulnerable to validity questions. Third, none of the preceding theories contributes to an understanding of the underlying cause of the conflict. Wars occur for a reason. World War II started largely because of the way World War I ended. Failure to understand the where the players stand relative to their causes is a serious shortcoming in a strategic wargame.

What is needed is a wargame-friendly theoretical model which combines the insights of punishment, denial, and five-ring theory; but also one which doesn't rely on overwhelming military might; one which takes into account asymmetrical strategic effects; and one which provides some insight into the underlying causes of the conflict. The next chapter will propose such a model.

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[i]Thomas Schelling, *Arms and Influence* (New Haven and London: Yale University Press,1966), 72.

[ii] Robert Pape, *Bombing to Win: Air Power and Coercion in War* (Ithaca & London: Cornell University Press, 1996), 4.

[iii] Ibid., 66.

[iv] Schelling, 1.

[v] Ibid., 3.

[vi] Ibid., 20.

[vii] Pape, *Bombing to Win*, 19.

[viii] Ibid., 10.

[ix] Ibid., 10.

[x] Ibid,. 16.

[xi] John Warden, "Success in Modern War: A Response to Robert Pape's *Bombing to Win*." Security Studies 7, no.2, (Winter 1997/98): 171.

[xii] Ibid., 173.

[xiii] Ibid., 183.

## Chapter 3

# Value-Based Strategic Effect Model (VBSEM).

> *"It is one thing to set up a mathematical model that appears to explain everything. But when we face the struggle of daily life, of constant trial and error, the ambiguity of the facts as well as the power of the human heartbeat can obliterate the model in short order."*
>
> —Peter Bernstein, author of Against the Gods (1996)

The following model is an attempt to resolve the problems identified in the previous chapter concerning reliance on overwhelming force, asymmetrical strategic effects, and the underlying causes of war. It builds on the previous strategic theories to produce a model which measures probable achievement of coercion. Finally, and equally important, it allows quantifiable variables in order for a computer-based strategic wargame to be able to employ artificial intelligence routines. For simplicity this chapter will assume war is between two states. Other states may be involved but only as a supplement to the primary actors.

This model is called the Value-Based Strategic Effect Model (VBSEM) because it uses the concept of value as its basis for quantifying relationships. Each side in a conflict continuously estimates its own value, that of its opponent, and that of the object in conflict. The key to VBSEM is understanding how each side views these values. These values can be classified into six variables: starting and current value, forecast benefit, probability of achieving benefit, attractiveness of benefit, current and forecast cost, probability of achieving forecast continued cost., and cost aversion.

VBSEM treats benefit and cost differently than the previous chapter. Here VBSEM treats benefit as achieving an increase in value (positive delta); that is, winning. Similarly it treats cost as experiencing a decrease in value (negative delta); that is, losing. Yet winning and losing don't necessarily mean won and lost. Increases and decreases in value are simply ways to keep score. It is the way that the players respond to winning and losing that determines who coerces and who gets coerced. The first step is determining value.

## Value: Starting & Current

The fundamental concept in VBSEM is the idea that each state has a value. Value is important because it is quantifiable. Identifying the appropriate values for each side helps to understand relationships and to keep score. It also allows incorporation of economic models to help minimize the inevitable reinventing of the wheel. Incidentally, this paper will incorporate very simple economic models even though very complex, sophisticated models could conceivably be used to achieve higher levels of accuracy.

VBSEM recognizes two types of value per state: the starting value and the current value. To determine a state's value, the VBSEM determines its power in five areas: military, political, economic, moral informational, and survival. Once tabulated for each side, the different power areas are compared to note the relative strengths and weaknesses which lead to asymmetrical strategies. The power rating in each area is then normalized and becomes a value rating for that element of power. The five power values are then summed and this becomes the state's total value. Starting value is the total value at the start of the game. Current value is the value at any point in time after the start. It is the starting value modified by the outcomes from operational and tactical events. These can be computed any number of ways. The big question, though, is why base a state's value on power?

A powerful state is a valuable state. Gibson, Ivancevich and Donnelly define power as "the ability to get others to do what another wants them to do."[i] A state that can get what it wants or needs is more valuable than one which can not. Plus different strengths and weaknesses compared separately as well as added together can frequently say more about a state than just the sum. A strength in one area (military power) can be overcome by weakness in another (political will). For example until the late 1980s, the former Soviet Union was thought to be a superpower because of its very strong military. Yet its military strength hid an even greater economic weakness which ultimately caused it to lose the Cold War.

Another potentially useful aspect of power is its ability to be treated as a zero sum game in certain situations. For example, one side can sometimes increase relative power simply by reducing that of its opponent. As one side moves closer to achieving a monopoly over some type of power, it can control supply dramatically increasing its value in that area.

As stated earlier, in VBSEM there are five types of power. The first is military power which is closely related to Pape's theories. This can be computed in a number of ways. Here it is done by converting operational lethality (people, weapons, effectiveness, etc.) into a normalized scale and plotting each state's position on the scale.[ii] This correlates roughly to the state's ability to use military force alone to achieve its strategic objectives. There are a few additional considerations necessary for computing relative military power. Sometimes a state will need to withhold a certain amount of military power from a conflict in order to ensure domestic security. These domestic security forces must be subtracted from the total force. If a state has close allies, sometimes it can "borrow" a certain amount of military power from its allies until the end of hostilities. Borrowed military power is added to the state's indigenous military power. One caution with borrowed power though is it may come with strings attached which could limit the options a state has for pursuing its strategic objectives. These strings could actually reduce power in another area, such as political or moral power. Also, allies may not remain allies for the duration of the war which could change the military power equation quickly. Finally, relative military power lends itself to zero sum calculations which allows a net loss in one side's force to function as an increase in the other's power.

The value of a state doesn't stop with military power. Each state also has economic power which roughly equates to the state's ability to achieve its strategic objectives through trade. It can also be measured in a number of ways. Here it is measured as a percentage of the world's total GNP normalized.

Political power is next and is often identified with Warden's Five Rings view on the importance of leadership. It roughly equates to the leader's job security. It encompasses both the degree of domestic support for the war from the political elite, and the vulnerability of the political leader to dissent. Usually political power is fairly high early in the conflict. As the war progresses, however, this support can change dramatically. If the political leader is vulnerable to dissent, these changes can have a large strategic effect on the outcome of the war. International support has an additive effect on this power.

Moral informational power refers to cultural support for the war. It equates to public opinion, attitudes and will. Few wars are possible without raising lofty appeals to a common sense of right and wrong. Moral informational power is strongest when the state is culturally homogenous in terms of values so that internal conflict are minimized. Moral informational power also increases when it has a widespread, multinational, or universal appeal. Obviously religious influence is the most frequent source of moral informational power. Some states, however, try to substitute a secular moral code for religion. An example here would be a concern for human rights. Finally, moral informational power can have a unique strategic effect on war. For example, military failure can spark a martyrdom, or circle-the-wagons, reaction which actually increases will and prolongs the losing side's involvement. Likewise, military victory can spark a sympathy reaction which decreases will and possibly leads to premature conflict termination.

Survival power is similar to Schelling's view of pain, and is the degree to which a state can feed and care for its people. It can be measured in many ways with one being average life expectancy. How long can the average person expect to survive in a given state? Typically during war resources can become scarce and require redistribution to aid the war effort. As access to food, water, medicine, and energy decreases, progressively more of the general population dies from shortages. A state with an unusually high mortality rate due to lack of food, water, shelter, medicine, or energy can't have much value.

Each of these types of power can be thought of as a measurement of the state's health in its respective area. High economic value equates to a healthy economy. After identifying the military, economic, informational, diplomatic, and survival values for each state in a conflict, the next step is to add these values together to determine each state's total value--starting and current. Once these values become known, determining benefit and cost becomes possible.

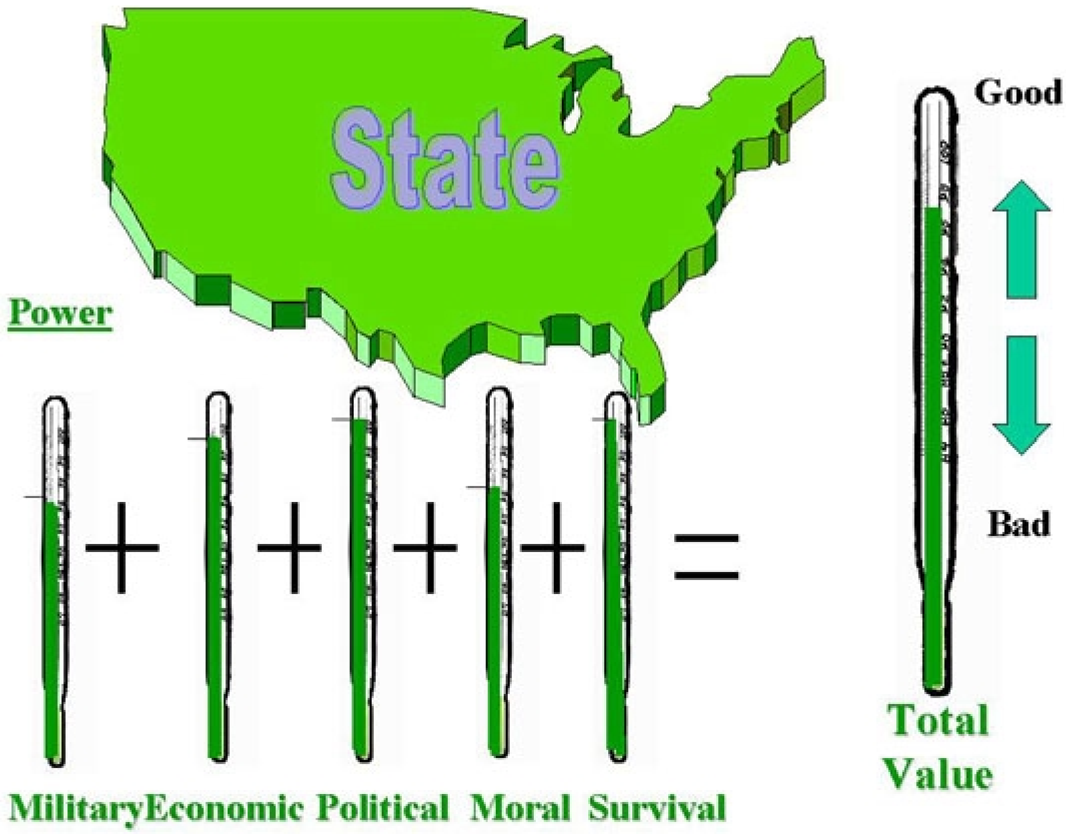


**Figure 3. VSBEM: "health" of the state directly related to its value**

## Forecast Benefit

Benefit is the amount of increase in current and/or forecast value above the starting value. In war both sides usually hope to increase their current value above the starting value by some target amount. Benefit provides the reason for starting a fight and for continuing to fight once started. Current benefit is the non-negative difference between starting value and current value. It shows whether or not a state is winning. If current value is below starting value, no benefit is being realized. Realizing no benefit to fighting is not necessarily a reason to yield early in the war. Most states enter war understanding that their value may decline below the starting value for a short period of time. Much like an investor, they are willing to accept a temporary setback if it means in the long run they end up “in the black”. This makes forecast benefit more important than current benefit. To determine forecast benefit, the current benefit must be known, and then weighted based on probability of increasing benefit and attractiveness of an increasing benefit. The key to using these variables is determining state value at any given point in time.

As easy as this may (or may not) sound, it’s actually very complicated once the war starts because increases in one value area can be offset by decreases in other areas. States typically try to pick simple strategies for improving value that are likely to avoid this problem. One popular strategy is to take valuable territory from another state, especially when that particular territory is rich in economic, survival, and political significance. Capturing such territory can increase the aggressor’s value by decreasing the other side’s relative military value, taking its economic resources, taking its survival resources, rallying its people in support, and coercing other states in to adopting its moral view. If other states of the world do not object, the aggressor can reap quite a harvest in value. Most, if not all, the major powers of the world have successfully employed this strategy at one time or another in their history. On the other hand, if other nations view the aggressors’s capture of territory by force as a future threat to their vital interests, they may use it as an excuse to turn the tables and capture his territory. If capturing territory is too risky, increases in value can also come by simply decreasing the other side's value. For example, assume two militarily powerful states are fighting, neither intends to retain its captured territory, and both are losing an unequal amount of military force. The state that has lost less military force will experience an increase in military value simply because the other side has lost even more force. On the other hand, the state that has gained the most military value might be losing the most total value due to corresponding decreases in economic, moral informational and political value.

Determining current value and forecast benefit is then the result of continuously summing the values of the five value areas for each state. The starting value provides the baseline. Current value relative to the starting value shows whether the state is winning or losing. The magnitude of the difference between current value and starting value for a given unit of time helps show the likelihood that winning will turn into won and losing will turn into lost.

## Probability of Achieving Benefit

The benefit or value of fighting depends on the probability of success. Determining it requires the strategic wargame take into account the magnitude and direction of change in each state's current values. Magnitude is the amount of change for a given unit of time. If one side experiences a tremendous positive value change in a short period of time (i.e. Germany, May 1940), it will likely expect that vector to continue to the end of the war. Likewise with a negative vector (France, 1940). As the war continues, value may fluctuate up and down, but the mean change in value will still be the key vehicle for determining forecast benefit. It isn't enough to just look at the vector in total state value either; an asymmetrical increase in one type of power may eventually negate or even reverse decreases in the other types of power (North Vietnam, 1968). But vectoring is only half the equation because war requires a sufficient preponderance of force to keep the vector positive (if winning). If the vector has been positive but the ratio of force between the two sides has become even, then the probability of success is actually smaller than might be expected. The amount of power (military or otherwise) available to a state relative to its opponent makes a difference. For example a state can have a large military, yet be unable to wage war effectively (small indigenous force plus (+) small allied force minus (-) larger military force needed to maintain political power). In most modern democratic states, little to no indigenous military force needs to be held in reserve to prevent an insurrection. In a dictatorship, a significant amount of military force may be needed and thus unavailable for war. Once the available military force drops to zero, if previous success had been due to military power, any historical positive value vectors will become moot—the probability of success will go to zero as well. On the other hand, even if the forecast benefit is positive, a state may still elect to support an early termination to the war simply because it isn't interested in a big increase in value.

## Attractiveness of Benefit

Not all states place the same importance on improving their value. Daniel Bernoulli once wrote the "utility resulting from any small increase in wealth will be inversely proportionate to the quantity of goods previously possessed."[iii] For example, a state at the very high end of the value continuum already has a great deal of value. There isn't much more it can gain (benefit) by involving itself in a war; however, it does have a lot to lose (cost). In this case, the real motivator to a high value state is in not giving ground to an aggressor. This is different than the low value state which has little to lose and everything to gain. Once the benefit (positive difference between starting value current or forecast value) is known, the next step is to determine the attractiveness of this benefit. A state that is winning (benefit) and is attracted to increasing its value even more (high attractiveness to benefit) may refuse to negotiate with the losing side for anything less than unconditional surrender. Multiplying the variables of benefit, probability of future benefit, and attractiveness of benefit gives the case for continuing the fight. But what about cost?

## Cost: Forecast & Current

Up to this point the discussion has centered on the positive increase in current and forecast value relevant to the starting value (the benefit variable in the cost-benefit model). But what about a decreasing current value; what about cost? Cost is current and forecast value below the starting value. When the state finds itself losing value as the war goes on, it is paying a cost. In other words cost equals losing. Cost is important because the war will generally end when the loser says it will end; that is, when the loser agrees to the winner's demands. Yet losing does not mean lost. Frequently in war one side will be losing only to turn the corner and ultimately win. All states accept a certain amount of cost early in the war, especially if the magnitude is small.

## Probability of Achieving Forecast Continued Cost

Probability of achieving forecast continued cost is simply the negative side of probability of achieving forecast benefit. Like probability-benefit, probability-cost is a function of magnitude-direction data and force available. If much value has been lost quickly, and if available force favors the other side, then the vector will suggest a straight line decrease in value until no value is left. Once no value is left, the war is over by default—there is no state left to resist the other side. Assuming no rational state would ever let itself be destroyed (Germany 1945 is a possible exception), when does a losing side decide it has lost?

## Cost Aversion

The amount of acceptable cost is a function of starting value. The state with a high starting value will be more averse to cost than a low starting value state.[iv] It literally has "a lot to lose." The low value state, on the other hand, is less cost averse because it has much less to lose; however, the low value state is also much closer to losing all its value. Once a state loses all its value, it cannot survive--much less fight a war. This degree of cost aversion needs to be weighted into the current costs being experienced by each state.

## VBSEM Conclusion

A strategic wargame can use the total values of competing states to understand the players, identify at any given time each state's degree of winning or losing, when the war is likely to conclude, and finally what types of problems each state find itself facing as it struggles for a better state of peace. A model is important because it identifies the processes the wargame should try to emulate. But models are just good ideas until operationalized. To help nudge this model out of the realm of "just another good idea" it needs someone to mechanize it. The next chapter will provide some actual formulas to try and help turn theory into practice.

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[i] James Gibson, John Ivancevich, and James Donnelly, *Organizations* (Boston, MA: Irwin, 1994), 369..

[ii] Trevor Dupuy, *Numbers, Predictions and War: Using History to Evaluate Combat Factors and Predict the Outcome of Battles* (Fairfax, VA: Hero Books, 1985), 40.

[iii] Peter Bernstein, *Against the Gods: The Remarkable Story of Risk* (New York: John Wiley & Sons, Inc., 1996), 105.

[iv] Ibid., 105.

# Chapter 4

# From Model to Wargame

*Between the idea and the reality, Between the notion and the act, Falls the Shadow.*

T.S. Eliot, poet

Models are nice, but how do you employ them? One way is to include in the strategic wargame an artificial intelligence (AI) module that can make decisions based on rules derived from VBSEM. Ideally the previous chapter would have provided sufficient guidance to get the AI programmer started. If not, this chapter will hopefully provide enough little picture answers to get help the ball rolling. Four computer wargame topics are covered here: players, databases, mechanisms, and a catch-all topic termed fuzzy logic.

## Players

Consistent with the Joint Pub definition of a wargame, there should be at least two sides. Which side should the computer play? The answer could be both, as long as toggles are provided for allowing operator input at any time. Letting the computer play both sides makes the action fairly predictable and easily understood. It also helps keep the operator(s) from getting bogged down with detail. Finally it allows the game to play real-time without continuous assistance from the operator(s). Letting humans take control introduces more irrationality (realism), and flexibility.

Making this question more complex is the interrelationship between a VBSEM-based strategic wargame and operational wargames. A VBSEM strategic wargame needs continuous inputs from an operational wargame (tactical wargame if simulating peacekeeping operations). These inputs are changes to the strategic environment caused by the operational wargames breaking things (military) or in some other way making changes in order to achieve objectives. Once it gets these inputs, strategic wargame tracks these changes, readjusts its "thinking," and decides whether or not to provide new guidance to the operational wargames. The operational wargames should also have an artificial intelligence module making operational decisions, and a human override option. Since there can be up to five operational wargames per strategic wargame, more than two players/AI modules could be required.

## Databases

One can't have a wargame without a database. A VBSEM strategic wargame should include at least four databases: starting value, power relational, current value, and potential cost/benefit. When an operational wargame indicates a change to either side's starting value, the computer measures the degree of change to the affected power base, modifies the value of the other power bases (if required), sums the new power base values, logs the new current value, modifies the potential cost/benefit database, and finally plots on a scale each side's willingness to continue the war.

Starting values is simply a list of each state's power base values at the start of the game. These values can be input directly by an operator or can be stored as default settings. These values can be determined in several ways. For example, Trevor Dupuy advocates computing military power by taking the overall number of weapons a country can bring to battle and weighting these weapons individually for their lethality in order to achieve an "overall weapons inventory value of a combat force."[i] A far simpler way is to follow Chris Crawford's example in his *Balance of Power* wargame and base an individual state's military power on "2 * number of soldiers * number of weapons / number of soldiers + number of weapons."[ii] However it is done, the military power base value should only include the power the state can use, not just what it has. Having a weapon of mass destruction doesn't count unless it can be delivered reliably. The other four power bases could be developed by similar means. These five power base values are then normalized and summed to create the starting value. Changes to starting value creates a new current value.

The power relational database is a list of rules regarding what happens to other power bases when one of them either exceeds or goes below certain thresholds. It would also use either default or pre-game operator-provided settings. The idea is that different types of power are interrelated. For example military power will collapse without food as measured under the survival power. If survival value decreases due to attacks on food stores, the state will try to redistribute food so that military value remains high even though others may starve. Eventually, however, a continuously decreasing survival value will be felt by the military causing its value to decrease as well. This point is a threshold. The power relational database would then describe the ratio of a further increase in survival power to decrease in military power. This, in turn, must become an input to the operational games supporting the model. It would do this also for the other power base values. For example, if a state's default starting survival power value was 90, then the power relational database might show that a decrease below 75 will cause economic power to decrease at a rate of 1:3, political power at 3:1, military power at 1:2, and moral informational power to increase at a rate of 1:1.5. Should economic power subsequently decrease below 62, then political power will decrease at an additional rate of 2:1,and so on.

The current state value database is simply a holding place for tracking changes in each state's power. Current value is continuously updated and referenced by other parts of the wargame.

The potential cost/benefit database is a list of objectives which can increase (benefit) and decrease (cost) power values, along with their notional value. Like the others, it would have default settings and an operator override. As the game progresses, the perceived value of these objectives will change based on the VBSEM mechanisms used.

## Mechanisms

If determining value is the most challenging part of creating a strategic wargame, proposing mechanisms for utilizing that data is probably the most contentious. Basically a strategic wargame should utilize at least four mechanisms: a benefit calculation mechanism, an operational hand-off mechanism, a cost calculation mechanism, and a termination mechanism.

The benefit calculation mechanism takes objectives from the potential cost/benefit database and modifies them according to Degree of Attractiveness and Probability of Achieving Benefit (see previous chapter). Degree of Attractiveness is a function of current value (Bernoulli). Probability of Achieving Benefit is a function of power advantages relative to the enemy and historical rate/direction of changes. If one side's Degree of Attractiveness and Probability of Achieving Benefit are both high, that player will likely not settle for anything short of unconditional surrender. If both were low, that player will probably want to negotiate a truce and this information would be passed to the termination mechanism. For example, assume one player has a relatively low overall starting value (high benefit attractiveness), views the harbors in the other side's territory as lucrative (potential cost/benefit database), and has a large military

military power advantage over its opponent (high probability of achieving benefit). The benefit calculation mechanism should tell the operational wargame to seize those harbors.

The operational hand-off mechanism is simply the interface between the strategic and the operational wargames. Through it the strategic wargame provides objectives/guidance and receives outcome information. Ideally it should be able to hand-off objectives/guidance and receive inputs to all five operational wargames concurrently.

The cost calculation mechanism is the negative side of the benefit calculation mechanism. It takes inputs indicating decreasing value from the operational wargames and determines readiness for war termination. It is a function of current value, Cost Aversion, and Probability of Achieving Forecast Continued Cost (previous chapter). If losing beyond a certain threshold, the cost calculation mechanism will see that state as desiring war termination at the earliest opportunity, and will notify the termination mechanism.

The termination mechanism simply plots and compares each side's willingness to end the war. The war ends either when both sides send a willingness to end message, or as soon as one side reaches the minimum possible current value. Once the war is terminated, the computer should revisit each state's current value to determine winner and loser. It should then review the final potential benefit database to identify potential future causes of conflict.

## Fuzzy Logic

Three more issues must be addressed before leaving this chapter: scope, probability, and lessons learned. All the discussion thus far has focused on two states fighting a war. A far more interesting and useful strategic wargame would increase the scope of the model to include the motivations of the other states within the region, to include coalition partners. Many if not all of these states will identify at least some of their current value with the fortunes of one of the antagonists; consequently, they will be initially motivated to help, hurt, or remain neutral. As the war progresses, however, they may decide to step in, step out or even change alliances. All of these decisions will be made based on a calculus of value and should be included in the wargame.

Probability should incorporated as much as possible into a strategic wargame. War is as much an art as a science. Information doesn't always come to decision makers immediately after an event in complete, objective packages. Even if they did, many times leaders hear what they want to hear and believe what they want to believe. The mechanisms identified above should incorporate a probability factor to account for the possibility that an actor could be receiving faulty information. If the termination mechanism would ordinarily indicate deterministically that a state should sue for peace immediately, it should be modified based on an operator input level of probable access to reliable information. For example, if the operator believes the opponent will have good but not perfect access to information, the termination mechanism should indicate a 90% probability of him or her choosing the computer suggested outcome, and a 10% chance of choosing another outcome picked randomly.

Finally, the most important part of the strategic wargame needs to answer is the lessons learned. A strategic wargame must be transparent enough to readily answer the "why" questions that will inevitably come up. Why did the opponent choose to negotiate war termination when it was clearly winning and able to achieve its opponent's most valuable objective? No wargame replicates the real world perfectly. To be truly useful the operator must be able to differentiate the valid lessons learned from the invalid.

## Chapter 5

# Conclusions

*"But war's a game, which, were their subjects wise, Kings would not play at."*

— William Cowper, English poet (1785)

It is much better to make mistakes in a wargame than in an actual war. This is particularly true at the strategic level. No one has a perfect understanding of war at the strategic level. Numerous theories exist but it is difficult to apply them reliably across the spectrum of war. Improving the fidelity of strategic wargames would help test theory, improve understandings, and prevent mistakes from occurring during the real thing.

This paper reviewed some of the current theories on strategic warfare, proposed a model of strategic effects, and offered ideas for incorporating that model into a strategic wargame. The next step would be to actually write the code and put the model into a wargame to test it. This, or something similar, needs to be done. War at the strategic level is far too important a process to trivialize its learning. Military power alone does not always work. The post-Cold War world is becoming too complex. Strategic effects must be quantified and clearly understood. If not, the potential for genuine national disaster is always only a heartbeat away.

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[i] Dupuy, 46.

[ii] Chris Crawford, *Balance of Power: International Politics as the Ultimate Global Game* (Redmond, WA: Microsoft Press, 1986), 32.

# Appendix A

# Terms and Definitions

The following definitions come from the United States Air Force Wargaming Institute, Prime Warrior Course.

**accreditation.** The official certification that a model or simulation is acceptable for use for a specific purpose. (DMSO Glossary of M&S Terms, p. 32 and; JCS Pub 1-02)

**aggregate level simulation protocol (ALSP).** A family of simulation interface protocols and supporting infrastructure software that permit the integration of distinct simulations and war games. Combined, the interface protocols and software enable large-scale, distributed simulations and war games of different domains to interact at the combat object and event level. The most widely known example of an ALSP confederation is the Joint/Service Training Confederation (CBS, AWSIM, JECEWSI, RESA, MTWS, TACSIM, CSSTSS) which has provided the backbone to many large, distributed, simulation-supported exercises. Other examples of ALSP confederations include confederations of analytical models that have been formed to support US Air Force, US Army, and US TRANSCOM studies. (DMSO Glossary of M&S Terms, p. 33)

**aggregated combat model**. A combat model which groups individual combatants into larger "units", typically using the real world hierarchical command organization of the force to determine these groupings. (Hartman, Chapter 1, p. 7)

**aggregation.** The ability to group entities while preserving the effects of entity behavior and interaction while grouped. (DMSO Glossary of M&S Terms, p. 33)

**algorithm.** A prescribed set of well-defined, unambiguous rules or processes for the solution of a problem in a finite number of steps. (DMSO Glossary of M&S Terms, p. 33)

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|---|---|
| **analog model**. | A model in which one system is replaced or simulated by an analogous normally physical system. Examples are the passage of continuous time is modeled by the physical sweeping hands of a clock. (Garrambone) |
| **analysis:** | The analytical investigation, quantitative appraisal and comparison of information subject to review in order to identify significant facts for subsequent interpretation. (Garrambone) |
| **analytic model.** | Models for which an exact numerical solution can be obtained. Examples are formulas and equations. (Garran bone). A mathematical model in which it is possible to work with its relationships and quantities to get an exact analytical solution. (Simulation Modeling and Analysis, Law & Kelton, p. 5) |
| **combat model**. | A simulation model used to describe the basic combat processes of fire power, mobility, intelligence, logistics, and command and control in order to estimate the results --numbers of casualties and survivors, resources expended, terrain controlled, etc., --of battles and wars. (Dictionary of Military Terms, Dupuy, p. 151) |
| **combat, military**. | A violent, planned form of fighting, in which at least one party is an organized force, recognized by governmental or de facto authority. One or both opposing parties hold at least one of the following objectives: To seize control of territory, to prevent the opponent's seizure and control of territory, or to protect one's own territory. The presence of weaponry creates an atmosphere of lethality, danger, and fear in which one party's achievement to objectives may require its opponent to choose among continued resistance (and thereby risk destruction), retreat and loss of territories and facilities, or surrender. (JCS Pub 1-02, p. 52) |
| **command and control** | The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. (JCS Pub 1-02, p. 77) |
| **concept**. | A notion or statement of an idea, expressing how something might be done or accomplished, that may lead to an accepted procedure. (JCS Pub 1-02, p. 84) |
| **data.** | A representation of facts, concepts, or instructions in a normalized manner suitable for communication, |

interpretation, or processing by humans or by automatic means. (DMSO Glossary of M&S Terms, p. 41)

**deterministic model**. A model in which the results are determined through known relationships among the states and events, and in which a given input will always produce the same output. (DMSO Glossary of M&S Terms, p. 44)

**deterministic.** Pertaining to a process, model simulation or variable whose outcome, result, or value does not depend upon chance. (DMSO Glossary of M&S Terms, p. 44)

**doctrine**. Fundamental principles and operational concepts by which the military forces or elements thereof guide their actions in military operations in support of national objectives. It is authoritative but requires judgment in applications. (JCS Pub 1-02, p. 118)

**dogma**. An authoritative principle, belief, or statement of ideas or opinion, especially one considered to be absolutely true. A system of principles or beliefs. (American Heritage Dictionary, p. 415)

**domain**. The physical or abstract space in which the entities and processes operate. The domain can be land, sea, air, space, undersea, a combination of any of the above, or an abstract domain, such as an n- dimensional mathematics space, or economic or psychological domains. (SIMTAX, p. 7)

**environment**. The texture or detail of the domain, that is terrain relief, weather, day, night, terrain cultural features (such as cities or farmland), sea states, etc.); (2) the external objects, conditions, and processes that influence the behavior of a system (such as terrain relief, weather, day/night, terrain cultural features, etc.). (DMSO Glossary of M&S Terms, p. 47)

**fidelity**. The degree to which a task or a training device represents the actual system performance, characteristics, and environment. (AFMAN 36-2234. P. 185). The similarity, both physical and functional, between the simulation and that which it simulates. (2) A measure of the realism of a simulation. (3) The degree to which the representation within a simulation is similar to a real world object, feature, or condition in a measurable or perceivable manner. See also: model/ simulation validation. (DMSO Glossary of M&S Terms, p. 50)

**game**. A physical or mental competition in which the participants, called players, seek to achieve some objective within a given set of rules. (DMSO Glossary of M&S Terrns, p. ) A set of rules completely specifying a competition, including the permissible actions of and information available to each participant, the mathematical probabilities with which chance events may occur, the criteria for termination of the competition, and the distribution of payoffs. (The American Heritage Dictionary, p. 546)

**granularity**. Fidelity and level of detail of objects and environment. See also: resolution. [FY93 Focus Call]

**ground truth**. The actual facts of a situation, without errors introduced by sensors or human perception and judgment. (DMSO Glossary of M&S Terms, p. 51)

**hex side**. One of the six sides of the hexagon. Sometimes rivers, ridge lines, fortifications, or some other feature run along the hex side. (Dunnigan, The Complete Wargames Handbook, p. 77)

**high resolution combat model**. A model which includes detailed interactions of individual combatants or weapon systems. Each combatant in a high resolution model has its own vector of state variables which describe its unique situation and its unique perception of the battlefield as the battle progresses. Interactions among combatants are resolved at the one-onone engagement level often computing separately the results of each individual shot fired in the battle. The engagement models include terrain and environmental effects as well as the states of the firer and target. (Hartman, p. 1-6)

**iconic (model).** A physical model or graphical display that looks like the system being modeled. (DMSO Glossary of M&S Terms, p. 53) Scaled "physical" representation of a real item. Adheres to the idea of "looks like". Examples are globes, maps, statues, model airplanes. (Garrambone)

**live, virtual and constructive model or simulation**. Models and simulations that involve real people making inputs into a simulation that carries out those inputs by simulated people operating simulated systems. [MSMP] (DMSO Glossary of M&S Terms, p. 56)

**measures of merit**. The dimensions, quantities, or capacities of some of value, excellence, or superior quality—normally estimated by evaluation or comparison. Also known as measures of worth. (Garrambone)

**military strategy**. The art and science of employing the armed forces of a nation to secure the objectives of national policy by the application of force or the threat of force. (JCS

**model fidelity**. A description of the level of detail portrayed about the performance of functions and tasks accomplished by the entities in a model. High fidelity models provide a greater degrees of detail in accounting for the execution of processes (e.g., attrition, movement, communications, logistics, etc.) than lower fidelity models. Low fidelity models contain less information about specific entity interactions and descriptions of sequences of events. Low fidelity models typically exclude, approximate, or summarize the results of various processes that are less important to the model user. Thus, they may allow the models to execute faster, with less requirements for storing information and tracking causality. (Hartman and SIMTAX)

**model resolution**. A description of the level of detail of entities portrayed in a model (e.g., numbered air force, air division, wing, squadron, flight, individual aircraft: army, corps, division, brigade, battalion, company, platoon, squad, soldier: individual tank, tank-platoon, tank-company, etc., or individual ship, battle group, task force. High resolution models include detailed interactions of individual combatants or weapon systems. Each combatant in a high resolution model has its own vector of state variables and its unique perception of the battlefield. Interactions among combatants are resolved at the one-on-one engagement level. Aggregated models groups individual combatants into larger "units", typically using the real world hierarchical command organization of the force to determine groupings. Aggregated models deal in average properties, behavior and results. (Hartman and SIMTAX)

**model**. A representation of some (generally only certain key) aspects or attributes of a system. (Garrambone) A physical, mathematical or otherwise logical representation of a systems, entity, phenomena, or process. (DMSO Glossary of M&S Terms, p. 58)

**monte carlo simulation**. A system in which random statistical sampling techniques are employed such that the result determines estimates for unknown values. (DMSO Glossary of M&S Terms, p. 60) An operations research technique which attempts to solve probabilistic "chance" problems by drawing many samples of individual outcomes from a large pool of possible outcomes and examines overall effects using statistics. (Garrambone)

**optimization**. To determine the best or most favorable condition, degree, or amount. To make as good as or as effective as possible . To make the most effective use of. (American Heritage Dictionary, p. 873)

**simulation.** A representation of a combat situation usually by means of a computer model. (Dictionary of Military Terms, Dupuy, p. 200) The process of designing a mathematical-logical model of a system and experimenting with this model. (Introduction to Simulation and SLAM II. Pritsker, p. 6) A two-phased process of constructing a model and conducting experiments with the model so as to understand the behavior of the system or evaluate strategies for its operation. (Garrambone)

**stochastic (model).** A model in which the results are determined by using one or more random variables to represent uncertainty about a process or in which a given input will produce and output according to some statistical distribution; for example, a model that estimates the total dollars spent at each of the checkout stations in a supermarket. Based on probable number of customers and probable purchase amount of each customer. Probabilistic model. (DMSO Glossary of M&S Terms, p. 72)

**stochastic.** Pertaining to a process, model or variable whose outcome, result, of value depends on chance. (DMSO Glossary of M&S Terms, p. 72)

**strategy.** The art and science of developing and using political, economic, psychological, and military forces as necessary during peace and war, to afford the maximum support to policies, in order to increase the probabilities and favorable consequences of victory and to lessen the chances of defeat. (JCS Pub 1-02, p. 350) The art and science of employing the armed forces of a nation or alliance to secure policy objectives by the application or threat of force. Military strategy sets the fundamental conditions of operations in war or to deter war. It establishes goals in theaters of war and theaters of operations. It assigns forces, provides assets, and imposes conditions on the use of force. (DA Field Manual 100-5 Operations, p 9) See Military Strategy

**symbolic (model).** Properties of a system are expressed with numerals, letters and other symbols. These are the most abstract type of model, are the easiest to manipulate, and have the greatest generality. Examples appear in reports as text and equations. (Garrambone) A model whose properties are expressed in symbols. Examples include graphical models, mathematical models, narrative models, software models, and tabular models. (DMSO Glossary of M&S Terms, p. 72) A model which represents a real system using mathematical equations or computer program. (Hartman, p 1-3)

**system**. A set of interrelated parts, ideas, functions, or procedures which together accomplish a purpose. (DARCOM Handbook 11-1.89, p.)

**war fighting**. Actual combat. (Shafritz, The Facts on File Dictionary of Military Science, p. 487)

**war game**: A simulation of a military operation involving two opposing forces, using rules, data, and procedures designed to depict an actual or assumed real-life situation. War games may be manual, with all decisions, assessments, and bookkeeping functions performed manually; computer-assisted; or completely computerized. (Dupuy, Dictionary of Military Terms, p. 227) A simulation, by whatever means, of a military operation involving two or more opposing forces, using rules, data, and procedures designed to depict an actual or assumed real life situation. (Quick, p. 496 and JCS Pub 1-02, p 393) A simulation game in which participants seek to achieve a specified military objective given pre-established resources and constraints; for example, a simulation in which participants make battlefield decisions and a computer determines the results of those decisions. (DMSO Glossary of M&S Terms, p.)

**war**. An armed conflict, of a state of belligerence, between two factions, states, nations, or coalitions. Hostilities between the opponents may be initiated with or without a formal declaration by any of the parties that a state of war exists. A war is fought for a stated political or economic purpose or to resist an enemy's efforts to impose domination. (Dupuy, Dictionary of Military Terms, p.227)

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