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# **A Dynamic Theory of Battle Victory and Defeat**

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Victory or defeat in battle is modeled as a set of flow charts for dynamic simulation. Two main causal pathways are: from material resources via logistics to firepower at point of assault; and from organizational morale (emotional energy, coordination, discipline) to maneuver. According to empirical research by the author and others, the crucial event is organizational breakdown, which is more strongly affected by maneuver than by firepower of assault, and which leads to battle victory or defeat. Casualties are more strongly affected by organizational breakdown than by assault firepower. Additional pathways lead to attrition, feedbacks to material resources and to morale, and to long-term war outcomes and geopolitical consequences. Revolutions in military technology do not require a separate model or new theory, since all technological innovations operate by changing the strength of pathways in the basic model. These models give a more precise understanding of Clausewitzian friction or “fog of war.”

## **Introduction**

Military power is a central variable in theories of geopolitics, state formation and growth, legitimacy, national identity, and other topics of historical sociology. On the level of historical events, military power comes down to winning or losing battles. Here I present a dynamic feedback theory of the multiple conditions and processes, both social and material, that determine battle victory and defeat. The model is necessarily complex. I will present it in a series of steps, starting from the basic model, and successively adding short-term and long-term feedbacks, and elaborating sub-models for parts of the overall system of variables.

The theory is based on my empirically-based analysis of the micro-sociological processes of violent confrontation (Collins 2008), on historical literature on battles (especially the American Civil War), and works of military doctrine. In this schematic presentation I will not cite this literature in detail, but will include brief illustrations of particular processes in battle. Systematic quantitative data are available only for portions of the model, and I do not present a test of the model, nor run any simulation experiments. The main contribution here is the overall architecture of the theory. This is best done by a series of flow charts. These provide the basis for future simulations.

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There have been three main theories of military victory.

- (1) Material resources, sometimes referred to as force ratios. Here victory goes to the side that has more troops, and more and better weapons. Since resources have to be brought into action, a related component is logistics, and further back in the causal chain, economic capacity of a society. Material resource theories emphasize both immediate preponderance of forces on the battlefield, and long-term application of resources for a campaign or war; over the longer time periods, these are theories of attrition, wearing down enemy resources until the larger force wins.
- (2) Maneuver. Victory comes through movement of forces; the side with greater speed or surprise disrupts the enemy and prevents it from using its forces effectively or even from responding at the point of attack. Through maneuver, a smaller force can defeat a much larger one, and major victories can be won with relatively few casualties on the winning side.
- (3) Superior élan, variously referred to as valor, bravery, or heroism. Victory occurs by one group of fighters imposing their will on their opponents, fighting harder, more fiercely and resolutely. In contrast to (1), which is material, rational and calculable, (3) is considered to be distinctively human, harder to explain, but palpably real in the moment of battle. It is sometimes described as having better quality troops, implying that it is a long-term attribute, although some theories invoke situational conditions – immediate social processes. Tolstoy (1865–69), describing the Napoleonic wars but applying his observations of the Crimean War, argued that the morale of the common soldiers outweighs both (1) and (2), the province of generals and their plans. Napoleon famously declared that in battle morale outweighs material factors by three to one. Military doctrine, incorporating both factors, holds that to guarantee success, an attacking force should outweigh its opponent by a factor of three to one. Élan is manifested at the point of attack and repulse, and thus in direct frontal assault, in contrast to (2), which largely avoids prolonged confrontation.

The three theories, often presented as mutually exclusive, imply each other at various points, although differing greatly in emphasis. Maneuver ultimately comes down to some fighting, and hence requires some moment of élan; and maneuver's greatest success is often regarded as breaking through into the enemy's logistics lines, thereby disrupting the flow of material resources. Conversely, material resource superiority can take account of maneuver by persisting longer and forcing a war of attrition. This was the strategy of General Grant in the US Civil War, in which the North had over three times the resources of the South, while the South had more trained officers (initially)

and better knowledge of local terrain, which resulted in better maneuver and élan.

Popular history, journalism, and political rhetoric extol yet another theory: Leadership – having a better general – is the main determinant of victory. However, military leaders operate through the main processes of the model; some are masters of maneuver; some induce particularly strong imposing of will, both on one’s own troops and on the enemy; some are good at logistics and the organization of large forces. All generals must address all three components to a degree; Napoleon was considered masterful at all three. Tolstoy, in contrast, insisted that the crucial condition of victory or defeat was endogenous to the short-term processes on the battlefield – a position supported by micro-sociological analysis of violence (Collins 2008). We will be in better condition to understand the empirical realities of “leadership” if we see it through the lens of the dynamic model.

Technology is sometimes regarded as a separate theory of military superiority, and advanced technology is held to outweigh all other conditions. US strategic planning (and budgeting) since the 1940s has emphasized leading all potential opponents in technological innovation. Since the 1990s it has been held that precision-guided weapons, sensor systems, satellite communications and computers are creating the most profound change in the history of warfare (Hammes 2004; McIvor 2005). The extreme claim is that Clausewitzian friction has finally been overcome, and thus the causes of battle victory shift to a new theoretical perspective. But I will argue that technology operates through the same basic components of material resources, morale, and maneuver; thus theory of military technological innovation has to be assessed as a further series of inputs to the basic model. I will provide this at the end of the analysis. At this point, we will be in a position to better understand the sources of Clausewitzian friction and the extent to that it can be eliminated.

## **The Basic Model: Material Resources, Morale, Maneuver, and Organizational Breakdown**

FIGURE 1 presents the central components of the model. There are two main causal paths. At the top of the flow chart, MATERIAL RESOURCES are mobilized by LOGISTICS, to bring force to the point of ASSAULT; this leads to CASUALTIES. At the bottom of the chart, MORALE leads both to intensity of ASSAULT, and also to MANEUVER; assault and maneuver jointly determine ORGANIZATIONAL BREAKDOWN.

The chief peculiarity of my model is that organizational breakdown is more important than the material force of assault – sheer firepower delivered – in causing casualties; it is after an army has broken down organizationally that it suffers most of its casualties, and not primarily through sheer physical

battering. This is a major discovery of the situational sociology of violence (see Collins 2008 for empirical and theoretical basis and further references). Again in the next steps of the causal chain: both casualties and organizational breakdown determine BATTLE VICTORY OR DEFEAT, but breakdown is the stronger condition.

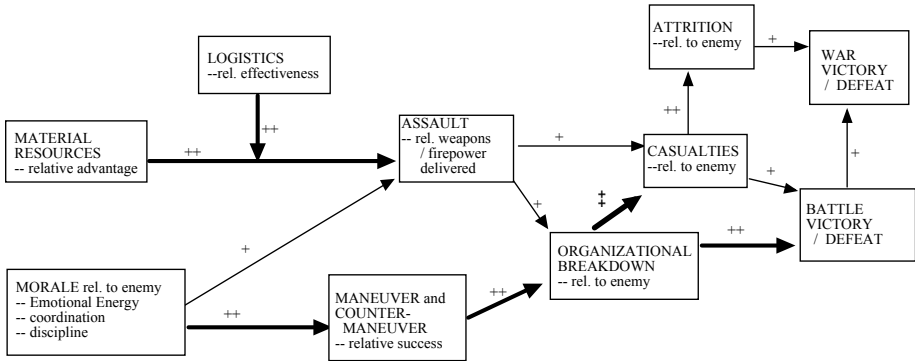


FIGURE 1. BATTLE VICTORY AND DEFEAT: BASIC MODEL

++ = strong causal path  
+ = moderate causal path

At the upper-right of the flow chart are two additional variables, ATTRITION and WAR VICTORY/DEFEAT. Attrition is distinguished from casualties because there are more ways to lose troops and equipment besides casualties; as we shall see later (FIGURE 3), several different paths besides enemy firepower cause losses. BATTLE VICTORY/DEFEAT is short-term; WAR VICTORY/DEFEAT is long-term, and accumulates both from battles and from other factors, that I have simplified here to attrition.

Throughout the model, all variables are in terms of relative standing of both sides in a war; for instance material resources are always expressed as relative advantage or disadvantage to the enemy; level of assault is relative amount of firepower compared to what the enemy delivers; etc. This has the important implication that an army does not have to operate at a very high level, but only higher than its enemy. In Clausewitzian terms, both armies suffer friction, but the one that undergoes less friction wins.

Each such variable is determined at a particular moment in time, and changes as quantities are used up or enhanced through feedback and exogenous replenishment.

Consider now the upper pathway starting with MATERIAL RESOURCES. These are the numbers of troops and their equipment. To bring them to the battlefield and the point of attack requires LOGISTICS, which again has a relative level of effectiveness compared to the enemy. Some resources are always used up in logistics; in addition, accidents, traffic problems, the speed and coordination of movement – or lack thereof – subtract some proportion of material resources by the time it reaches the point of attack. ASSAULT – i.e. firepower delivered sufficiently accurately on target – results in the material destruction of violence: CASUALTIES suffered by each side, in troops killed and wounded, and in loss of equipment. Firepower is a term of convenience; the model is general and encompasses all other use of weapons, including pre-modern ones.

So far the model is straight-forward and commonsensical. It is sheer slug-it-out with victory going to the more richly supplied army and the big battalions; the only complication is the effectiveness of logistics, the comparatively banal side of combat that nevertheless tends to prove crucial, at least in battle campaigns that are more than brief and local (Van Creveld 1977).

Turn now to the lower line of causal flow. MORALE, again relative to the enemy, is made up of a number of components. It includes emotional energy, a continuum ranging from feelings of confidence, enthusiasm, and initiative at the high end, down through foreboding, depression, and passivity at the low end. Emotional energy is abbreviated EE; the concept is spelled out in the micro-sociology of social interaction and emotional dynamics in Collins (2004). EE can exist at the level of the top command (highly energetic and aggressively confident generals such as Alexander, Napoleon, and Robert E. Lee); at the level of the officer corps in general, or its subcomponents; and at the level of ordinary soldiers. The strength of the US military is considered to be in the high level of initiative taken by NCOs and junior officers, a quality also found in the German army in WWI and WWII; in contrast, many Third World armies are considered to be very weak at the NCO level, because of excessive subservience to hierarchy (Shils and Janowitz 1948; King 2006).

As we shall see, feedback loops from combat events affect EE, especially for the mass of the troops.

In addition, MORALE includes discipline, the extent to which troops and the chain of command obey orders; and coordination, the degree that the different components, both within and across units, act together smoothly, or are out of synch and mutually disrupting. Here I have departed from the traditional narrower concept of morale as fighting élan; an effective fighting force might not be very fierce, but have very strong discipline to obey orders; or again, it might not be very respectful to authority, but have a high capability of acting together to produce a coherent set of activities. Here I will lump all of these together as social processes – as contrasted with material conditions – that set off a series of consequences in the conduct of battle.

MORALE, together with MATERIAL RESOURCES delivered through LOGISTICS, jointly determine ASSAULT. I propose that the strength of the upper pathway is greater; the sheer volume of firepower delivered is more strongly determined by the material flow of armaments and munitions than by troop morale. This may be over-simplified; troops with high emotional energy, and/or coordination, and/or discipline may fire their weapons at a higher rate compared to troops lower in these social qualities. There is considerable evidence (Marshall 1947; follow-up studies summarized in Collins 2008; King 2006) that many troops on the front line do not fire at all, and most fire very inaccurately. The relative importance of sheer material firepower available, vis-à-vis social factors, in determining the amount of fire delivered on target, is susceptible of empirical analysis, but I do not cover the fragmentary literature here.

The most important thing that flows from MORALE is MANEUVER. Here I include counter-maneuver: the response of one side to the opponent's maneuver. Sometimes the response is inadequate, in which case the maneuvering forces produce a breakthrough or at least bring superior forces to bear on a point where they gain a local victory through a higher level of assault; sometimes the second-mover successfully blocks the maneuver, resulting in a renewed stalemate; on occasion, the second-mover caps the first maneuver with an even more striking counter-maneuver. Maneuver generates a lot of friction, and thus is hard to carry out; many maneuvers fail because the troops cannot move fast enough, lose their way, become uncoordinated, etc. This friction is overcome by factors from the MORALE box. Strong discipline is one of them. The enthusiasm of sheer emotional energy also can enable an army to maneuver successfully.

Example of successful counter-maneuver: The celebrated battle of Chancellorsville, in 1863, is an instance where the Northern General Hooker made a successful encircling movement around the west end of Lee's line; Lee responded by an even more extended circling movement around the west end of Hooker's line, resulting in heavy casualties and breakdown of the Northern forces and an ignominious retreat by a larger army in the face of a smaller (McPherson 2005). Example of victory through strong discipline: Confederate General Stonewall Jackson, who carried out the flanking move at Chancellorsville, was a ferocious disciplinarian who treated his troops harshly but made them move considerably faster than other troops. Example of victory by group enthusiasm: General J.E.B. Stuart and other Confederate cavalry officers, as well as Union cavalry officers such as Sheridan, were very popular among their troops and carried out flamboyant long-distance movements, often with high success and low casualties (McPherson 2005); similarly with the White Army general Wrangel in the Russian Civil War of 1918-20 (Klusemann 2010).

In military history, maneuver is frequently considered a matter of brilliant strategy; but when successful it often has an element of improvisation, rapid seizing of opportunities, and these are results of MORALE. Aggressive initiative falls within the definition of emotional energy; this applies above all to the field commanders, but also there is an necessary element of EE on the part of the troops, as well as coordination and discipline if the movement is to be carried out. Thus strategic brilliance is more in the social conditions of situational flow and execution than in detached strategic planning. Most American Civil War victories did not result from strategies actually carried out as planned (Griffith 1989; McPherson 2005). Strategy does not need to be modeled separately.

The most important result of MANEUVER is to bring about ORGANIZATIONAL BREAKDOWN. More precisely, both sides have an organizational coherence to maintain; the variable could be labeled in that fashion, but I have put it in reverse, to highlight the importance of an organization breaking apart, as the key to victory and defeat. ORGANIZATIONAL BREAKDOWN is relative; both sides are always breaking down to a degree, under the stress of combat; both are suffering Clausewitzian friction, and the more they attempt to move from one place to another, to disassemble one formation and reassemble it somewhere else, the more friction they risk. Thus both combat – the physical destruction of ASSAULT – and MANEUVER tend to break one’s own organization down. Offsetting this is the extent to that the enemy’s organization breaks down. (ORGANIZATIONAL BREAKDOWN should be read as a positive quantity for the side which has the advantage.)

Example: at Chancellorsville, as in most other clear-cut victories, most of the casualties taken by the loser happened after the organization had broken down; disoriented troops were unable to fight back, and took many casualties from forces that suffered few. (For other evidence, including both ancient and modern battles, see Collins 2008.) Thus the path from ORGANIZATIONAL BREAKDOWN to CASUALTIES is stronger than the path from ASSAULT to CASUALTIES. There is also a path that leads from ASSAULT to ORGANIZATIONAL BREAKDOWN, but this is weaker than the path leading in from MANEUVER.

This point is so central that the entire theory might be called *the organizational breakdown theory of battle*. Social processes are central to holding an army together as an organization. When social cohesion is high – not just sufficient but enthusiastic – it can result in successful tactical maneuvers; if these catch the enemy’s timing off, they can lead to rapid turning points, in which one organization deteriorates rapidly, and the other battens on it to destroy it physically. Without such turning points, where the organizational coherence of the two opponents diverges rapidly, battles are



mostly matters of attrition, either stalemate or slow gains and losses, without decisive consequences.

This is so even though élan can also be channeled into sheer frontal assault. Napoleon and Lee were sometimes successful at this; but they also failed – Napoleon at Waterloo, Lee at Gettysburg – since frontal attack on a prepared defensive position tends to take very high casualties where concentrated high-firepower weapons are used (Biddle 2004). Thus although MORALE can flow directly into ASSAULT, its more powerful effect is when it flows into MANEUVER.

The biggest victories tend to come about via the lower path in FIGURE 1. Left to itself, the upper path has few decisive results unless one side is greatly superior to the other in resources (well beyond the 3-to-1 rule of thumb). On the right side of the diagram, ORGANIZATIONAL BREAKDOWN has a strong path to BATTLE VICTORY/DEFEAT, while the latter has only a moderate path from CASUALTIES. What is considered a victory or defeat is a social construction of the participants themselves. In decisive battles, there is general agreement on both sides as to the outcome, and the publicly announced label is not contested (although credit and blame may be). Some battles are indecisive, a stalemate with no victor announced. What determines the amount of consensus is chiefly the feeling of emotional dominance, although other criteria are also invoked, the more so if preponderance by different criteria are inconsistent. Victory and defeat is above all an emotional condition; although physical destruction contributes to a degree, it does so jointly with the more powerful causal lines flowing from morale and organizational coherence.

At Chancellorsville, all three of the usual criteria favored the Confederates: one side was routed and felt itself beaten; the same side took the most casualties; the victors ended up in possession of the ground. Sometimes the criteria diverge: an army can take heavy casualties and still be regarded as victorious, because the other side is emotionally dominated, one side exultant and the other depressed, one organization more broken down than the other, even though the victor took a great deal of physical battering in bringing about this result. An example is Grant's victory at Shiloh in 1862, where the North lost 13,000 to the South's 10,000 (McPherson 2005). Moreover, holding ground is not a necessary criterion of victory. Stonewall Jackson's campaign in the Shenandoah Valley in 1862 was considered a brilliant series of victories through fast-moving maneuver, although he never stayed to occupy the battlefields where he defeated the enemy (McPherson 2005). In some routs, the defeated army is so badly disorganized that it does not take very high casualties. An example is the German *Blitzkrieg* victory in France in 1940, where so many French troops were encircled and captured that the physical casualty rate was low relative to the size of forces (Keegan 1997).

## Short-term and Long-term Feedback from Battle Processes

Consider now FIGURE 2, beginning with the lower pathways. First, notice that I have added causal arrows feeding into the relative success of MANEUVER and into ORGANIZATIONAL BREAKDOWN, from *accidents and local conditions*. This indicates there is a role of chance in affecting how successfully movement of troops is carried out, including local terrain, weather, and other incalculable events and conditions. These were omitted from FIGURE 1 in order to present the basic model more clearly. Technically, these can be entered into the model by multiplying each path by a random fraction. The role of chance variations is important in fitting real historical conditions, since otherwise a model dominated by positive feedback loops would make initial advantages cumulate inexorably without the reversals so often observed.

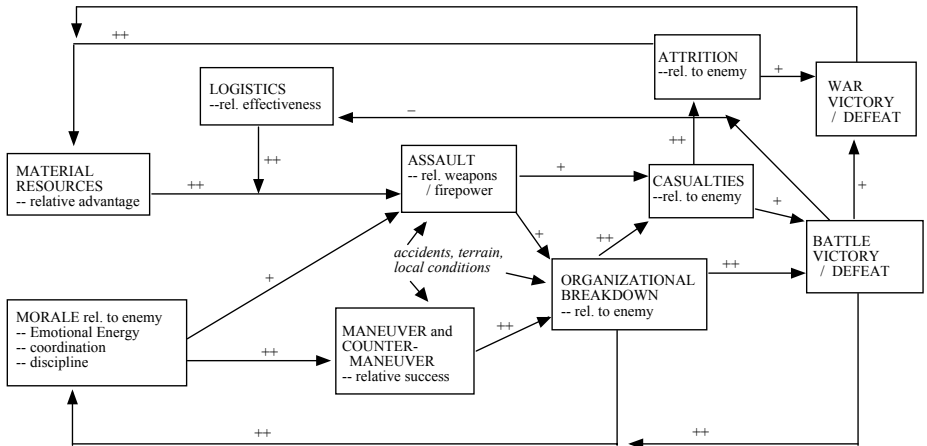


FIGURE 2. BATTLE VICTORY AND DEFEAT: FEEDBACKS

++ = strong causal path  
 + = moderate causal path

ORGANIZATIONAL BREAKDOWN feeds back into MORALE; army units that have made an enemy break down feel more confidence and enthusiasm (EE). Conversely, an army that has been broken down has plummeting morale – low confidence and energy; frequently the disciplined chain of command is weakened, even after the battle is over and organization is nominally restored; and coordination suffers.

MORALE and ORGANIZATIONAL BREAKDOWN appear to be two boxes containing the same thing. They differ in their placement in the time-

sequence: ORGANIZATIONAL BREAKDOWN is the moment of combat and its immediate aftermath; MORALE is the more long-term condition of the army. These should be measured separately.

Turchin (personal communication) suggests there is an important pathway from long-term morale to the degree of resistance to organizational breakdown. Troops with more cohesion stand up better at the crisis of battle (a pattern often noted in Caesar's *Gallic Wars*). This path can be added in the full model but is omitted from Figure 2 in the interests of visual simplicity.

Taken in isolation from other factors, ORGANIZATIONAL BREAKDOWN (read as a positive quantity for the side that has the advantage) feeds back into MORALE. The successful army gains emotional resources that will make it better fighters in the future; the broken army tends to reproduce the conditions for future defeats. For example, the long series of successes by Lee's Army of Northern Virginia during 1862 and early 1863 gave it energy and aggressiveness, even though its material logistics were poor and it was generally outgunned on the battlefield (McPherson 2005).

However, these processes do not happen in isolation; thus a broken organization can be replaced or reorganized, given sufficient exogenous material resources and logistics. After each of the major defeats suffered by the Northern armies at the hands of Lee and others in 1861-3, they would withdraw, replace officers and men, and eventually come back in sufficient strength where their superior numbers told; after late 1863, morale in Union armies tended to rise. This was a period of rising proportion of victories, although casualty levels in the Union army were very high (McPherson 2009). This implies that victory has a stronger effect on raising morale than casualties do in depressing it. Evidence calculated from desertion rates following battle victories or defeats with varying levels of casualties supports this point (Denig 2010).

There is also a feedback from BATTLE VICTORY/DEFEAT to MORALE; this is in addition to the loop from ORGANIZATIONAL BREAKDOWN, since there is another path leading into BATTLE VICTORY/DEFEAT from the level of CASUALTIES, that also affects the intensity of victory/defeat. The intensity of victory and its effect on morale can be independent of organizational breakdown inflicted. E.g. Sherman's march through Georgia in late 1864 had little fighting. Since the northern army had an overwhelming force ratio over the enemy, 6 to 1, the enemy did not disintegrate so much as avoid battle, while Sherman's troops engaged in massive destruction of material resources. This victory was largely through the material pathway. But this victory too – widely celebrated when Sherman reached the sea – greatly enhanced Northern morale, and depressed the Southerners, large numbers of whom surrendered soon after (McPherson 2005). Here, the inability of the Southern army to prevent its material resources being destroyed, generated a strong sense of emotional dominance.

Consider now the upper feedback loops in FIGURE 2. ATTRITION leads directly into WAR VICTORY/DEFEAT, independently of the path from BATTLE VICTORY/DEFEAT. (ATTRITION relative to the enemy is read as a positive quantity for the side that has the advantage.) Losing a war is not merely a matter of losing battles; one can also lose because attrition mounts, so that resources are run down and the army is no longer capable of fighting. Lee's army in Virginia continued to win most of its battles, even after the disastrous defeat at Gettysburg in July 1863, but eventually gave up when its material resources became too palpably overmatched. Lee's only major defeats happened when he went on offensive campaigns into the North, at Antietam, Maryland in 1862, and Gettysburg, Pennsylvania in 1863. On his home territory, Lee continued to fight a series of defensive battles during 1864, in which he almost always inflicted heavier casualties on the enemy, kept possession of the battlefield, and repelled the enemy. But Grant, pursuing a strategy of attrition, kept bringing increasing numbers of troops and advancing obliquely towards the Confederate capitol; finally in 1865, Lee's numbers and logistics were reduced so low that a small defeat that blocked him from his remaining supply lines forced him to surrender (McPherson 2005).

And even before a war ends, ATTRITION feeds back into MATERIAL RESOURCES. For an army taking casualties, this is a negative feedback, running down one's resources; but the overall balance between the opponents depends on the level of resources replenished exogenously by each side minus the amount of attrition each suffers. Attrition on some occasions can become a positive feedback, in the case where an army captures supplies or military equipment from the enemy.

FIGURE 2 adds another long-term feedback, from WAR VICTORY/DEFEAT to MATERIAL RESOURCES. Distinct from whatever destruction and capture takes place during the war, the aftermath of victory can involve annexing territory, or stripping conquered territory of its assets. Here we shift to the geopolitical realm of long-term processes, whereby war victors gain cumulative advantage that makes them stronger for the next war, and the defeated lose assets that increases their chances of future defeats.

Sometimes the resources gained or lost are not just equipment and supplies but troops themselves; in ancient wars of the Persians, Macedonians, and Romans, and in ancient and medieval wars in China, Korea, and Mongolia, conquering armies generally enlisted defeated bodies of troops in their own armies. This pattern of generating a positive feedback loop of forces has generally disappeared since the rise of nationalist ideologies.

## **Reversals and Negative Feedbacks**

As noted, modeling battle processes solely in terms of positive feedback loops carries the danger of historically unrealistic runaway processes, in which small initial advantages expand cumulatively without possibility of reversal. Greater realism is introduced in four ways.

- (a) Conditions of weather, terrain, and other accidents can be modeled as random variations in the strength of the causal pathways. How strong is the role of chance could be tested by fitting models with large or small random components.
- (b) Exogenous conditions enter into the model (although these are not explicitly indicated in Figure 2 and elsewhere). Most importantly, MATERIAL RESOURCES can be replenished, and one side may have deeper reserves than the other. Thus in WWII, German resources were eventually used up on the Eastern Front despite initial victories, whereas Soviet resources from deep in its territory were eventually mobilized, turning the tide into a cumulative process in the opposite direction.
- (c) A negative feedback loop is introduced from BATTLE VICTORY / DEFEAT to LOGISTICS. More specifically, when victory leads to territorial conquest, the advancing army takes on greater logistics costs, whereas the retreating army reduces its logistics costs as it shortens its distance from its resource heartland. This was an important process in the Russian civil war of 1918-20, where both White and Red armies made long advances into enemy territory, which were stopped and reversed by the difficulties of long logistics lines (Klusemann 2010). This feedback loop operates in addition to other pathways in the model; the Red army eventually won, in this instance, as its level of resources came to outweigh those of the Whites.
- (d) Territorial conquest produces a negative feedback loop in an additional way: alien troops engaging in resource stripping, looting, and humiliating the conquered population tend to enrage the losing side (Turchin, personal communication). Thus a more complex version of FIGURE 2 would add a negative path from BATTLE VICTORY / DEFEAT to MORALE. Morale of the defeated army rises following these atrocities, increasing their desire for vengeance; morale of the victorious army also tends to fall, if it relies heavily on looting, since this reduces army discipline and makes soldiers more concerned with their material fortune (this is describe both by Tolstoy, and by Klusemann 2010). However, this negative feedback loop appears to have a distinct time-pattern; morale swings from response to atrocities operate in the medium run, perhaps up to one year; but if

conquered territory is held for a long period (perhaps 5 years) resignation and loss of morale sets in. These time-patterns can be more precisely measured.

## The Attrition Sub-Model

FIGURE 3 gives a partial model to make clear the pathways that flow into ATTRITION. Casualties caused by the enemy are generally the strongest but not the only source of attrition of troops and equipment. An additional, moderate source comes from MANEUVER. Troops became exhausted on rapid marches, drowned, hurt in traffic accidents, get lost or find opportunities to desert the field of battle. Some are shot or imprisoned by their own officers or battle police. In pre-mechanized history, horses died, just as vehicles break down or collide. Most routes of maneuver are strewn with casualties and debris of various kinds.

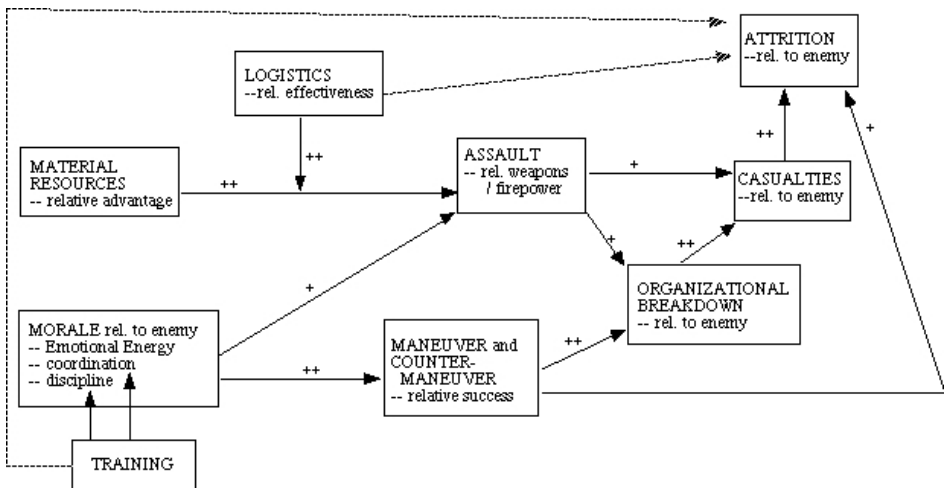


FIGURE 3. ATTRITION: FULL MODEL

ATTRITION is also fed by LOGISTICS mobilization. On the whole, logistical transfer of supplies and equipment is like maneuver, subject to the same problems although usually with less hurry (suggesting that the rate of attrition during maneuver is higher, per volume moved). Traffic accidents cause a considerable portion of lives and injuries; estimates are on the order of 15-20% of all casualties (Keegan 1976; Collins 2008); the era of helicopter

transport continues to keep this ratio high, since these are intrinsically dangerous forms of transportation, especially under military conditions, where flight schedules are ad hoc and easily disrupted. Moving munitions is a particularly dangerous source of attrition via logistics; a substantial number of non-combat casualties come from accidents in moving munitions, or in fires or other accidents in storage areas. A major danger of combat is not simply the enemy; the combination of large numbers of heavy equipment and lethal weaponry creates potential for very destructive accidents. So-called friendly fire, when troops are hit by their own forces, is included in the path from ASSAULT to CASUALTIES. Not all combat casualties are caused by the enemy; the inaccuracy of fire generally causes a modest but relatively constant proportion of losses inflicted by one's own side, whether being shot by oneself or by fellow troops. These are another result of the high emotional stress of combat, and may be especially high during organizational breakdowns.

Under the heading of logistics we may add another source of attrition that was extremely common until the 20th century: the hazards of camp life between battles created conditions of poor sanitation, exposure to weather, crowded quarters, and poor supplies of food and water that caused many losses through sickness. Such losses have become uncommon in modern armies with abundant material resources. Since the underlying issue is to deliver sufficient supplies of all necessities to troops in the field, during a defeat, even a modern army may find these conditions unavailable. For instance the huge losses in Soviet, German, and Chinese armies during World War II through logistics shortages, including high attrition rates of prisoners who were last in logistics priorities (Keegan 1997).

Finally, there is a non-negligible path from TRAINING to ATTRITION. Modern armies place great emphasis on training to produce coordination and discipline; thus casualties here fall under the basic process of building up the MORALE box. A proportion of troops are injured and killed during training, for roughly the same reasons that attrition happens during logistics operations.

## **Innovations in Military Technology**

FIGURE 4 models the portion of the basic processes that are affected by technological innovation. Technology is a long-term factor, not much affected by short-term battlefield feedbacks.

Throughout the 20th century, and with increasing emphasis from World War II onwards, military and political leaders have stressed the crucial importance of having a technological advantage over the enemy. This was dramatized particularly by German V-1 and V-2 rockets, and by the development of nuclear weapons, leading to the tendency to regard possession

of the ultimately powerful weapon as overriding all other conditions of victory and defeat. Superiority of fighter aircraft (easily measured by ratios of air combat victories to losses in numbers of aircraft destroyed) also added to the obsession with technological superiority of weaponry.

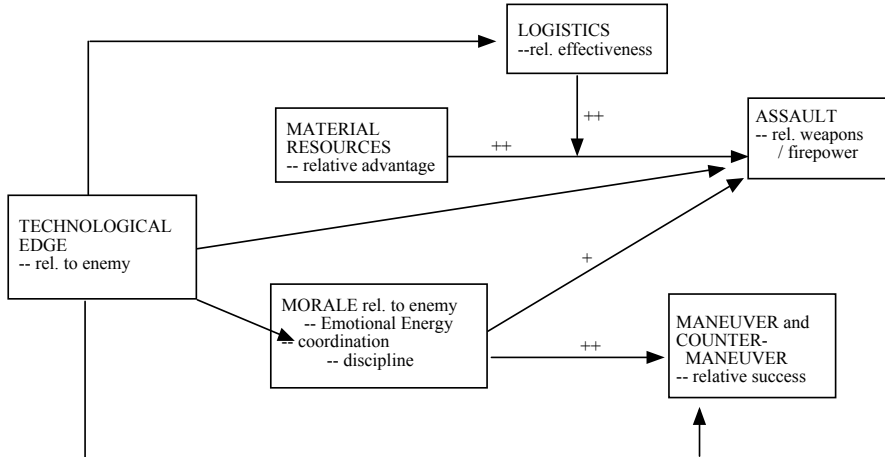


FIGURE 4. TECHNOLOGICAL INNOVATION

++ = strong causal path  
+ = moderate causal path

By the 1990s, US military doctrine emphasized technological innovation transforming all aspects of weaponry as well as coordination, command and control: precision-guided munitions; targeting by lasers, infra-red heat signatures, and computer-processed optics; surveillance and precise geographical positioning from satellites and other aerial vehicles; and the use of computers for fire control and organizational processes. It has been argued that these technological changes amount to a “Revolution in Military Affairs” (RMA), so sweeping that the principles of warfare are now changed, outdated all previous military doctrine (McIvor 2005).

Nevertheless, inspection of FIGURES 1-3 suggests that technological innovation can be modeled in general terms that do not require changing any of the basic components of the flow-charts. Historically there has always been a technological aspect to warfare. This can be modeled, abstractly, as a single factor, TECHNOLOGICAL EDGE. Like other factors in the battle dynamics model, it is a relative quantity: the relationship between the effectiveness of one side’s technology and the enemy’s technology.



As we see in FIGURE 4, TECHNOLOGICAL EDGE affects every major component on the left and central parts of FIGURE 1, with one exception: TECHNOLOGICAL EDGE does not affect MATERIAL RESOURCES, since that consists of sheer numbers of troops and numbers of various kinds of equipment. Technological innovation however may indirectly affect aggregate levels of material resources. It can reduce material resources, when new weapons become much more expensive, hence relatively few can be produced. E.G. the American B-2 stealth bomber costs over \$1 billion USD each, so that only 20 have been built. Or technological innovation can increase material resources, when they are very easy to build and have low maintenance costs; e.g. the Kalashnikov AK-47 automatic weapon, that has accordingly spread on a world scale. I do not attempt to model these connections in FIGURE 4, since that would involve expanding the model to include economic production processes, financial resources, etc. A more elaborate model could be constructed as desired.

TECHNOLOGICAL EDGE affects material resources as effectively delivered in combat, however, via LOGISTICS. Thus innovations such as steamboats, railroads, trucks, airplanes, helicopters have made it possible to move troops and equipment faster and longer distances to battlefields. Again, the question of relative effectiveness needs to be examined in detail; high-tech innovations may also produce more logistics burdens, such as fuel for transportation equipment. Thus with the advance of technology, the size of the actual combat forces compared to the logistical component (the so-called “tooth-to-tail ratio”) has grown, from on the order of 1 to 4 in 19th century armies, to 10 to 1 in early 21st century high-tech armies. (In guerrilla armies the ratio is not known precisely, but likely is close to that of traditional armies.) And technological innovation in weaponry (as distinct from innovation in logistics) can also add to the logistics burden; a US army M1A1 tank with virtually indestructible ceramic armor and enormous firepower weighs 60 tons, and thus cannot be transported more than one at a time by the largest cargo plane; hence during the 2003 Iraq invasion, an armored division had to be slowly transported by ship (Gordon and Trainor 2007). Thus it cannot be taken for granted that technological innovation – giving an edge in defensive and offensive battlefield power – necessarily gives an edge in logistics or other components.

The usual focus on the effectiveness of military technological is direct comparison between weapons in battle. This is the path from TECHNOLOGICAL EDGE to ASSAULT. High precision munitions, with their accompanying sensor and targeting systems, have increased the accuracy of long-distance fire (by aerial bombing, rockets, artillery, armored vehicle fire, etc.) to a level much higher in the 2003 US/Iraq war than in the 1991 Gulf War, and that in turn higher than bombing and firing accuracy in WWII (Murray and Scales 2003). Much of the improvement has been in accuracy

rather than in destructive power of explosives per se, that was already high at the time of WWII and even WWI (Biddle 2004).

Accuracy of long-distance weapons is one way of remedying the major problem of all infantry in close range combat: the tendency of most soldiers not to use their weapons at all, or to fire wildly (Marshall 1947; Collins 2008). Long-distance weapons such as artillery did not suffer from the emotional effects of confrontational tension/fear; but such weapons were intrinsically rather inaccurate. MORALE was thus traditionally more important for close-range ASSAULT than for long-distance firing. Current weapons technology in effect attempts to make all weapons into long-distance weapons, but with high degrees of accuracy.

Nevertheless, as we have seen, the paths from ASSAULT to CASUALTIES, ORGANIZATIONAL BREAKDOWN, and ultimately BATTLE VICTORY/DEFEAT are not the strongest paths to those outcomes. Hence increasing sheer firepower does not necessarily guarantee battle victory. This set of relationships is somewhat obscured by the fact that technological innovation can also affect all the social/ emotional/ organizational components of an army, hence the empirical effects are hard to disentangle.

To illustrate this with the current “Revolution in Military Affairs,” consider the pathway from TECHNOLOGICAL EDGE to MORALE. Computerization has affected the latter especially via its subcomponent, coordination. Highly centralized computer controls, connecting every front-line weapons platform (i.e. tank, vehicle, artillery piece, aircraft, etc.) with a command-and-control structure, has been used increasingly. It has been argued that computer links make for better coordination in all phases of a battle, eliminating costly errors that played a major part in Clausewitz’s friction (also known as “the fog of war”). The verdict is still out on the extent to that this has happened (McIvor 2005; Watts 2004). There are competing doctrines of how computer links should be organized: a highly centralized system (where a war can be run from a command post many thousands of kilometers away from the battle); or a horizontal network-centered battlefield, in which local units communicate and share information with each other directly, thereby responding more quickly and flexibly. There are no available studies (at least in unclassified publication) that definitively address this point.

My conclusion is a wider one: technological innovation can (as in the case of RMA) simultaneously increase ASSAULT firepower, generate LOGISTICS benefits and costs, and change coordination (in the MORALE) box. If battlefield victories or defeats change (e.g. the rapid conquest of Iraq in March 2003; but also the long struggle for pacification in the 6 years that followed), we cannot easily attribute this to just one component, such as widely-touted high-precision bombs, or more recently, remote-controlled drones. Every path in the overall model (FIGURES 1-4) needs to be investigated empirically,

before we can assess their relative contribution to battle outcomes, and long-term war outcomes.

Finally, there is a path from TECHNOLOGICAL EDGE to MANEUVER. Computerization of communications makes it possible for forces to move on the battlefield in complex maneuvers, and a technological edge here makes the difference between a fast-moving force (such as US forces in March 2003), and a slow-moving or stationary opponent (Iraqi forces) (Murray and Scales 2005). Thus TECHNOLOGICAL EDGE does not necessarily shift battles away from classic tactics of maneuver, and onto an exclusive reliance on superior firepower (the crude image of a super-weapon that devastates the enemy). Several conclusions follow.

First: A high-tech army may simultaneously attempt to maximize the advantages of ASSAULT and MANEUVER; this was the strategy of US commanders both in the 1991 Gulf War and in the 2003 Iraq invasion. General Schwarzkopf's "left hook" from Kuwait into Iraq in 1991 was directly modeled on the 1863 battle of Chancellorsville. In general, US military doctrine incorporates all the components of FIGURE 1 (McIvor 2005). Its goal is not only to destroy enemy forces (CASUALTIES) but to bring about "systemic collapse" including the command-and-control systems of the enemy, in effect to precipitate ORGANIZATIONAL BREAKDOWN.

Second: MANEUVER can compensate for shifts in the strength of ASSAULT. Biddle (2004) presents evidence there is no sudden shift in the effectiveness of firepower with the RMA of the 1990s; but that artillery and massed infantry fire (machine guns) was already so lethal in World War I that tactics had to be modified. Frontal assaults on defensive positions guaranteed heavy casualties to the attacker; by 1918 a solution was found, to break up the massed formations of traditional armies, and to disperse into small independent units that took advantage of local cover and concealment, in order to infiltrate enemy positions (Biddle 2004). In effect, this was a shift to MANEUVER and away from ASSAULT. World War II also placed great emphasis on maneuver, chiefly via mechanized warfare and *Blitzkrieg*. In this progression, the technology of extremely lethal munitions (through precision targeting) since 1990 has produced even more dispersion. An army that is inferior in ASSAULT – because it lacks the TECHNOLOGICAL EDGE – can compensate by increasing MANEUVER. Here I extrapolate beyond Biddle's conclusions, which do not cover guerrilla war.

In effect, this is what guerrilla tactics do; they disperse forces to an extreme degree, infiltrate enemy positions in small numbers, attack isolated targets, and quickly disperse again into positions of hiding. The objects of attack are vulnerable components of the enemy organization, especially in its logistics train – comparable to the goal of classic maneuver to break through the enemy's front into the supply lines. Thus the shift to guerrilla war and so-called terrorism, touted by some as an unprecedented new era in the history of

war, is a predictable adjustment to greater lethality of ASSAULT. In the multi-causal model of FIGURES 1-4, a weakness in one component can be compensated elsewhere. This is what happens in the shift to guerrilla war in response to very great inferiority in TECHNOLOGICAL EDGE.

This is not the only possible configuration. Two armies may both have a high degree of technological modernity, including precision-guided weapons systems, computer controls, etc. A conceivable example would be a war between the US and China in the middle of the 21st century. This would not be an asymmetric war (between high-tech and low-tech forces, and hence between very centralized and decentralized – i.e. guerrilla – war styles), but a symmetrical war. A likely scenario is that both sides would use the full array of their firepower (ASSAULT), initially in long-distance precision munitions, resulting in high levels of CASUALTIES on both sides; my conjecture is that victory or defeat would hinge upon the more volatile (and less predictable) tipping-point conditions via the pathway from MANEUVER to ORGANIZATIONAL BREAKDOWN. A parallel here would be the German invasion of France in 1940. Considerable technological modernization had taken place in both armies; both had approximately the same number of tanks and other weapons as well as total forces. German victory resulted from using tanks for rapid maneuver, whereas the French did not (Keegan 1997).

Third: all historical periods of military technology can be encompassed in FIGURES 1-4. Technological innovation does not call for a separate model, and does not give grounds for asserting that the basic principles of battle dynamics change with different technological epochs. The characteristics of particular technological regimes, however, can be more clearly specified by showing how they affect the pathways in this composite model.

## **The Link between Battle Dynamics and Geopolitics**

Battle dynamics determine victory and defeat in the short run, and in the somewhat longer run, war victory and defeat. I have commented briefly on how the consequences of the latter feed back into a society's pool of material resources (including population). Geopolitical theory is even more macro and long-term, explaining the shifting patterns of the territorial power of states (Collins 1978, 1995; Turchin 2003). The model of battle dynamics can be nested inside a larger geopolitical model. A composite model would add links from such factors as territorial size, natural resources, geographical position and distance from other state regions, into the main variables on the left side of FIGURE 1. Since material resources enter battle dynamics by being transformed into specifically military resources (trained soldiers, weapons, munitions, transport, etc.), a sub-model for the strength of the economy in each state would be needed; this would include not only the elaboration of

market relations, and the level of industrial production, but also financial structures, and fiscal extraction apparatus of the state. For instance, Hobson (1997) shows that during World War I, England had a more effective system of taxation than Germany, which in turn was more effective than Russia; hence their material resources could be extracted for military purposes at different rates, affecting overall performance in the war.

Economic conditions for technological innovation could also be added, further complicating the set of linked models.

The causal chain would also include the degree of state penetration into society, which affects not only extraction of material resources, but mobilization in the MORALE box. Mann (1993) gives evidence on how this mobilization was done in different European societies in the century leading up to 1914. One limitation of Collins' prior geopolitical theorizing (Collins 1978, 1995) is that it is largely confined to inputs into MATERIAL RESOURCES in specific geographical locations, and neglects inputs into the lower half of FIGURE 1. Turchin (2003) remedies this emphasis.

A full-scale model linking geopolitics with battle dynamics would therefore be quite complex. As pragmatic matter of theory building and testing, only segments of this can be managed at any one time. My paper aims to contribute to one part of this overall picture.

## **Operationalization and Tests**

Theories of military victory have been largely confined to readily available measures of the top portion of FIGURE 1 and 2: MATERIAL RESOURCES in numbers of troops and weapons, and CASUALTY counts. TECHNOLOGY has been operationalized by Biddle (2004) as the year of introduction of newer weapons systems. The speed and efficiency of LOGISTICS could be measured in principle although this has rarely been done systematically. Quantitative measures are not so easy to come by for the variables in the lower and central parts of the model. ORGANIZATIONAL BREAKDOWN, the key feature in this theory, can be measured by reading histories of battles and assigning a numerical level to the degree of organizational breakdown. This is not difficult to do, since organizational breakdown, when it happens, is very noticeable and a central point in most historians' accounts. Similarly, the degree of MANEUVER AND COUNTER-MANEUVER is prominently mentioned in historical descriptions, and can be given a numerical value.

Long-term MORALE of the army also should be susceptible to this kind of transformation of qualitative accounts into numerical ratings; additional measures such as desertion rates can also be used (Denig 2010). The issue of military morale remains under-theorized in this model. Further analysis on

this point (Lynn 1996; Turchin 2003; Noe 2010) can contribute to a more sophisticated sub-model.

Rival theories can be tested by modifying the FIGURES 1-3 to give prominence to their favorite causal paths. Theory which emphasizes material resources or force ratios simplify to a model in which RESOURCES produce CASUALTIES and ATTRITION and thereby VICTORY/DEFEAT.

Maneuver theory, as indicated, would have to operationalize historical accounts with numerical values; here the strong pathway predicts MANEUVER largely determines VICTORY/DEFEAT. My full model is most similar to maneuver theory, with the additional key process of ORGANIZATIONAL BREAKDOWN; thus the test here would be largely a matter of assessing whether MANEUVER alone predicts better than the full set of processes in FIGURE 2.

The theory of battlefield élan places all its emphasis on the strength of ASSAULT. Antecedents for this are generally left vague. One could operationalize several well-known suggestions: “battle-hardened veterans” can be operationalized as the number of previous battles of the troops on each side; alternatively, this may be interpreted as the level of morale arising from previous experience, operationalized as the previous experiences of victory by troops on each side. Yet another possibility is the length of time troops have spent in training (in principle, easy to measure, although the numbers are not easily accessible); and the quality of training (more difficult to measure). Yet another measure would simply be observers’ rating of the degree of ferociousness of troops in a particular battle. (Julius Caesar’s observations of the ferociousness of Gauls and other barbarian troops vis-à-vis calmer but more disciplined Roman troops suggests the élan theory in itself will not fare well.)

The value of a general apart from all other variables could be tested by giving each commander a score of previous victories and defeats, and to observe if this notably increases victory in comparison to the full model.

Finally, theories of “new wars” based on post-modern conditions (Kaldor 2001; Shaw 2005; for critique, Malesevic 2010) can be translated into the terms of the full simulation model. These “new wars” focus largely upon difficulties of globally distant logistics against locally-raised, small-scale logistics and local plunder for guerrilla-style resistance, and greater emphasis on civilian morale as overriding or controlling military troop morale. Again, I suggest these are largely modifications of variables within the larger model.

On the whole, it is unproductive to concentrate on only one or two conditions as determining military victory and defeat. This would only be worthwhile in theory-building if some factor turned out to dwarf all others in its effects. Historically, from the earliest times through recent computerized precision warfare and its guerrilla response, no such master factor has shown

itself. The path to an explanatory scientific theory is to put aside polemics and build comprehensively, incorporating what works.

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