International Journal of Development and Conflict
4(2014) 01–34

A RATIONAL CALCULUS OF WAR AND PEACE: APPLYING THE ROI OBJECTIVE FUNCTION TO MILITARY STRATEGY

BRETT D. STEELE*
Associate Professor
Institute for International and Civil Security
P.O. Box 127788
Khalifa University, Abu Dhabi, UAE

This article furnishes an analytical approach to military strategy by applying a return-on-investment (ROI) model of a commercial industrial firm. A fundamental relationship thus emerges between a military campaign's profitability and (1) the lethality level and frequency of its discrete attacks, (2) demand-side investments in propaganda design and distribution processes, and (3) supply-side investments in operational design and tactical processes. While presenting the common analytical foundation of military and business strategies, the significant differences between their output's average-benefit and average- cost functions are revealed. As a result, a systematic means is furnished for analyzing military strategy of both conventional and irregular warfare.

Keywords: Return on investment, cost, benefit, strategy, propaganda, tactical, operational

1. Introduction

Defense economists have made substantial contributions to the analysis of the technological supply side of warfare. "Supply side" refers to the organization for and execution of destructive attacks against enemy targets, with a focus on the relationship between production cost, production rate, and the product's performance characteristics. This achievement was prominently revealed in the pioneering scholarship of Hitch and McKean (1960), Peck and Scherer (1962) and Scherer (1964), and displayed more recently in the illuminating analysis of Brauer and van Tuyll (2008). A rigorous economic analysis involves more than the supply of goods and services, however, even when considering those of a destructive nature. It must also consider the societal demand side. This "demand side" perspective examines the subjective value or utility the market places on the goods and services being produced, or in a military context, the political value placed on particular attacks or acts of destruction. Curiously, the central paradigm of neoclassical economics to consider the interaction of both the supply side and demand side has not transferred significantly over to defense economics, despite the scholarship of such capable

*Email: brett.steele@kustar.ac.ae

demand-side researchers as Hallwood (2013) and Abdelfattah, et al (2013). Compared to the "military production function," defense economists scarcely recognize the "military marketing function," a process taken more seriously by media scholars O'Shaughnessy (2004), Jowett and O'Donnell (2012), and Taylor (2003), as well as counter-insurgency analysts such as Munoz (2012). The scholarship of Hartley (2007) and Smith (2009) also suggest that investments in military propaganda, humanitarian operations, public diplomacy, and even targeting choices to stimulate the political demand-side of a military campaign are given a low priority in defense economics. Given that the prominent US military failures in Vietnam, and to a lesser extent in Korea, Lebanon, Somalia, Iraq and Afghanistan, are directly related to such demand-side weaknesses, this neglect is ironic.

This article consequently seeks to better integrate the supply and demand sides of military strategy by developing a return-on-investment (ROI) model of a product design-and-manufacturing firm. As a result, a "rational calculus of war" theory emerges for allocating both demand-side and supply-side investments within the full scope of the military system.[1] The ROI model was originally derived for the commercial industrial domain by Steele (1995 and 2013). Its independent physical variables are production/sales rate and product-performance level(s). Its independent investment variables on the supply side involve creating the product design and the production & distribution process. Its independent investment variables on the demand side are designing the sales argument ("marketing investment") and in producing and distributing the sales argument ("advertising investment"). This elementary yet rigorous mathematical model represents a fundamental objective function for the strategic management of the industrial firm in terms of specifying investment allocation and technical-performance parameters. It is especially powerful since it reveals consistent mathematical relationships regardless of the technology or markets involved. As a result, the ROI objective function can be used to analyze a wide range of strategic reasoning in industrial enterprises throughout history—from Watt to Wozniak, so to speak. Given the unwillingness of economic historians to utilize quantitative microeconomic theory to construct their narratives of entrepreneurship and technological change, as articulated by Baumol (2010), this is hardly an insignificant development.

The perception that quantitative business or cost-benefit reasoning offers little utility for strategic military thought remains pervasive, despite the efforts of defense economists, as well as rational-choice theorists of International Relations such as Bueno de Mesquita. This was especially apparent in the U.S. Department of Defense (DOD) following the Vietnam War, given its flawed application during that conflict (Schultz, 1979). Luttwak (2001, 41) reveals such bias against economics when he declares that "In the realm of strategy, therefore, economic principles collide with the demands of war-effectiveness," and that "commonsense economic thinking does not apply when it comes to strategy."

[1] Mahnkin (2013) argues that while the idea of a utilitarian rational calculus of war is fine in theory, it is problematic in practice due to the difficulty in predicting both costs and benefits associated with a military campaign. But controlling such variables to hold them within politically acceptable limits is precisely why such vast effort goes to developing armed forces, which are subject to highly disciplined hierarchical command and control systems that seek to conform to the logic of close-loop feedback control systems.

Spinetta (2008) further underscores such antipathy by revealing how costs are formally disregarded when the US DOD develops strategic campaign plans. This U.S. Air-Force officer's exposé builds on the strategic analysis of Warden (2005) where combat costs are a major consideration in his strategic reasoning about air power. Likewise, no economic equations appear in Mahnken and Maiolo, (2008), although they do commence with a classic argument of Bernard Brodie concerning the utility of economic reasoning for strategic military thought (Brodie, 1949). One can also point to that curious catechism of U.S. war colleges concerning the need to balance "ends, ways, and means" of warfare instead of maximizing the difference between the value of the "ends" and the costs of the "ways" and "means." Therefore, demonstrating the applicability of the commercial ROI objective function to military strategy is a pressing task. This article will consequently address how the economic concept of profitability is actually well established in the iconic literature of military strategy, and that the basic dependent and independent variables of the ROI objective function are valid in the military domain. This paper will then show how the concept of business investment differs for the strategic management of warfare. Significant variations exist in the relationships between the dependent benefit and cost variables, and the independent technical and investment variables. The military ROI objective function that emerges, however, is directly applicable to both the development of armed forces and its political utilization in warfare from both supply-side and demand-side perspectives.

2. Literature Review

Applying business reasoning to warfare is hardly a novel idea. Although rarely acknowledged, the most influential military strategists operate within the same consequentialist moral paradigm. Sun Tzu, Thucydides, Clausewitz, Mao, Galula, and more recently Warden all deployed quite explicit, utility-seeking or cost-benefit reasoning where a politically profitable outcome is sought. More recently, Colin Gray (2007, 51) declared that "strategy is about making hard choices based upon cost-benefit guesswork." Profit in this military sense implies the difference between the political benefits of the war's end results and the costs and losses associated with the ways and means of waging it. Despite his contempt for the mathematical analysis of Tempelhoff, Bülow, and Jomini, Clausewitz in *On War* is so explicit in his use of quantitative instrumental or economic reasoning that Plehn (2005) displayed it graphically. Clausewitz (1976, 92) wrote, "Since war is not an act of senseless passion but is controlled by the political object, the value of this object must determine the sacrifices to be made for it in *magnitude* and also in *duration*. Once the expenditure of effort exceeds the value of the political object, the object must be renounced and peace must follow." (Italics mine) In other words, sue for peace to avoid a Pyrrhic victory upon concluding that the war cannot be profitable. Clausewitz (1976, 572) goes so far as to compare the culminating point of a military invasion to a business's breakeven point by writing, "It is therefore important to calculate this point correctly when planning the campaign. An attacker may otherwise take on more than he can manage and, as it were, get into debt…" Mao Zedong was equally comfortable with systematic economic reasoning in his central writings on military strategy. In *On Protracted War*, he distills the essence of revolutionary warfare down to fighting in a profitable manner to ensure the growth of the insurgence force into a formal conventional army that can defeat those defending the targeted capitalistic state. He referred explicitly to such reasoning as the principle of "fighting profitable decisive engagements and avoiding unprofitable ones" (Mao, 1938, paragraph 100).

Given how David Galula's influential strategic writings on counter-insurgency warfare directly involved countering the revolutionary-war strategy of Mao, it is not surprising that he also relied on explicit economic reasoning. Galula (1964, 8) wrote, "In the revolutionary war, therefore, and until the balance of forces has been breached, only the insurgent can consistently wage profitable hit-and-run operations because the counterinsurgent alone offers profitable and fixed targets." The concept of military profitability became especially meaningful for Americans during the final stage of the Vietnam War (Finsterbusch and Greisman, 1975). Brauer and van Tuyll (2008) described more recently the cost-benefit or profit-seeking reasoning of early modern European military commanders when deciding whether or not to fight battles. Likewise, Collier and Hoeffler (2004) drew similar conclusions after conducting in-depth empirical analysis of how much the pursuit of financial profits shapes civil conflicts. Finally, Sullivan (2007) uses such economic perspective to explain why powerful states can be defeated militarily by weaker states when the stakes are relatively low for the former.

If military campaigns are viewed as the organized production and delivery of discrete acts of destruction or "destructs" to inflict involuntary costs on an enemy in exchange for desirable resources, the similarity to business transactions is clear. By contrast, the commercial free-market exchange takes place in a voluntary, relatively un-coerced manner, and lawful commercial firms usually seek only financial resources from customers. In both cases, however, a profitable or at least a loss-minimizing outcome is sought, as evidenced by both peace and commercial negotiations. When viewed from this exchange perspective, many other similarities emerge between the strategic thinking associated with commercial production and military destruction. The technological performance of a product is analogous to the lethality performance of a destruct. The production rate is analogous to the destruct's rate of fire or launch rate; unit-production cost and unit-sales price are analogous to the military organization's average variable cost incurred and average benefit received from its launches of destructs, respectively. Likewise, the basic investment parameters from the ROI utility model of an industrial firm can also be applied directly to the military domain.

From a supply-side perspective, the production investment is analogous to the military's investment in tactical capability, while the design investment is analogous to the military's investment in operational art or planning.[2] Such military investments or short-term fixed costs represent resources expended to enhance the capability of an armed force and are independent of the actual destruct-delivery rate. Therefore, weapon-system acquisitions and both operational and tactical maneuvers represent military investments,

[2] As Col. L. D. Holder wrote in the 1982 edition of FM 100-5, "Formally distinguishing operational art from tactics is far more than a sematic exercise…As a link between strategy and tactics it governs the way we design operations to meet strategic ends and the way we actually conduct campaigns." (Naveh 1997, 11–12).

while ammunition expenditures and front-line human and hardware losses are not. From a demand-side perspective, investments in marketing (the design of the sales argument) and advertising (the distribution of the sales argument) are equally applicable to the military domain as the process of designing and distributing propaganda suggests. Both investments need to be coordinated to enhance the political perception of the benefits gained by launching the destructs in combat. This article thus demonstrates how both business and military strategy have supply-side and demand-side components, where the central strategic question is how to maximize one's net utility or ROI by selecting an optimum distribution of investment resources, as well as the optimum performance and frequency of its output. However, despite these similarities, critical differences emerge when examining the destruct's average cost and average benefit as functions of launch rate and lethality performance. This is due, in part, to the enormous role that human costs play in military strategy relative to business strategy, assuming the latter is subject to basic deontological ethical constraints.

3. The Military ROI Objective Function

As adopted from guidance and control theory, the "objective function" refers to the relationship between the independent variables that systems can directly control and the outcome they seek to achieve, subject to a wide range of unpredictable environmental factors and responses. Using profit, net-utility gain, or net present value as an ultimate goal, however, may be problematic. It cannot distinguish between efficient and inefficient utilization of resources and sacrifices, especially when comparing options over the same time period. Return on investment or net gains over total investment generally avoids such limitations and therefore provides a more rigorous strategic analysis within realistic investment limits.

The derivation of a generalized ROI relationship for a commercial product in Steele (2013) was subject to such simplifying assumptions as ignoring the time value of money, assuming the firm manufactures just one product with only one technical performance parameter, the product is manufactured over a finite product life cycle, and the probability of success is constant for both the dependent variables: average sales price and average production cost. The resulting equation is

$$\mathrm{ROI} = \frac{[B(z,q,M,A) - C(z,q,D,P)]qT}{(M + A + D + P)} - 1 \tag{1}$$

where

B = average sales price or *benefit* function
C = average production cost function
z = product's technical performance level
q = product's production rate
M = marketing or sales-argument design investment
A = advertising or sales-argument distribution investment
D = product's design investment

P = production and distribution system's investment
T = product's life cycle

When considering the gains of a marginal increase in investments, one can subtract from the profit achieved with new levels of investments the profit achieved by relying on the existing knowledge and capability of the industrial firm without making these investments:

$$\text{ROI} = \frac{[B(q,z,M,A) - B_o(z,q)] - C(z,q,D,P) + C_o(z,q)]qT}{(M + A + D + P)} - 1 \quad (2)$$

where $B_o(z, q)$ and $C_o(z, q)$ are respectively the unit-sales price and unit-production cost functions the industrial firm is capable of achieving without any additional investments. This approach is especially useful in situations where substantial investments have already been made.

To develop the military ROI objective function for the purpose of this analysis, it is assumed that only one type of weapon or "destruct" is used to attack an enemy force or asset. The lethality or performance level, z, of the destruct, as well as its launch rate, q can thus be established. Likewise, the distribution of the allocated resources for this campaign, including its investments in the operational design, D, production or tactical system, P, political marketing, M, and advertising, A, to maximize the ROI objective function can be assessed. A military campaign is viewed as the attempt to produce and deliver destructs to enemy forces to secure desirable political, economic, or ideological benefits in a profitable manner. For armed non-state actors, such as drug lords or insurgent leaders, the business ROI objective function may be an extremely valid model when seeking to build the power and wealth of the militant organization. This is especially the case when the costs associated with human and material combat losses are viewed as direct or variable, like raw materials and labor wages, since they depend directly on the production or launch rate of the destruct. For conventional state-owned military forces, however, the basic objective is not to invest in order to build up the power and wealth of their organization. It seeks instead to execute the objectives of the executive leadership with the least total cost to their state, which includes the loss of its fallen soldiers. In such a situation, it is much more difficult to privilege investments in improving the capability of the military system over the combat losses endured. Both represent costly sacrifices or investments to the constituent population. Therefore, the military ROI objective function for conventional forces differs significantly from a business ROI objective function. For the former, both the cost function and investment variables must be aggregated as the total investment. From this perspective, Eq. 2 becomes:

$$\text{ROI} = \frac{[B(q,z,M,A) - B_o(q,z)]\, qT}{[(C(q,z,D,P) - C_o(q,z)]qT + (M + A + D + P)]} - 1 \quad (3)$$

This equation can be subjected to a basic optimization analysis of taking its derivative with respect to each independent variable and setting them equal to zero. The resulting simultaneous equations can then be solved to determine the independent variables that can maximize ROI for given algebraic models of the average attack-benefit- and average attack-cost functions. These resulting equations, starting with the derivative of ROI with respect to the attack rate are

$$\frac{\partial \text{ROI}}{\partial q} = \left[\left(\frac{\partial B}{\partial q} - \frac{\partial B_0}{\partial q}\right)(C - C_0) - \left(\frac{\partial C}{\partial q} - \frac{\partial C_0}{\partial q}\right)(B - B_0)\right] q^2 T + \left[\left(\frac{\partial B}{\partial q} - \frac{\partial B_0}{\partial q}\right) q + (B - B_0)\right](M + A + D + P) = 0 \tag{4}$$

$$\frac{\partial \text{ROI}}{\partial z} = \left(\frac{\partial B}{\partial z} - \frac{\partial B_0}{\partial z}\right)\left[(C - C_0) + (M + A + D + P)/(qT)^2\right] - \left(\frac{\partial C}{\partial z} - \frac{\partial C_0}{\partial z}\right)(B - B_0) = 0 \tag{5}$$

$$\frac{\partial \text{ROI}}{\partial M} = \left(\frac{\partial B}{\partial M}\right)\left[(C - C_0) qT + (M + A + D + P)\right] - (B - B_0) = 0 \tag{6}$$

$$\frac{\partial \text{ROI}}{\partial A} = \left(\frac{\partial B}{\partial A}\right)\left[(C - C_0) qT + (M + A + D + P)\right] - (B - B_0) = 0 \tag{7}$$

$$\frac{\partial \text{ROI}}{\partial D} = \left(\frac{\partial C}{\partial D}\right) qT + 1 = 0 \tag{8}$$

$$\frac{\partial \text{ROI}}{\partial P} = \left(\frac{\partial C}{\partial P}\right) qT + 1 = 0 \tag{9}$$

Equations 6 through 9 can be simplified to

$$\left(\frac{\partial B}{\partial M}\right) = \left(\frac{\partial B}{\partial A}\right) = \frac{(B - B_0)}{\left[(C - C_0) qT + (M + A + D + P)\right]} \tag{10}$$

$$\left(\frac{\partial C}{\partial D}\right) = \left(\frac{\partial C}{\partial P}\right) = \frac{-1}{qT} \tag{11}$$

In short, optimizing the magnitude and returns of a military campaign is a complex, yet illuminating exercise in nonlinear analysis, even under the simplified assumptions assumed here. This highlights Clausewitz's seemingly naive admonition, as quoted above, to just accept defeat and negotiate for peace when the campaign's profitability becomes negative. As the ROI objective function suggests, many investment options exist to boost (or move to the right) the state's average attack-benefit function and push down (or move to the right) the average attack-cost function to regain the prospect of a profitable outcome that falls short of maximizing ROI.

While equation 3 conforms to the consequentialist logic of utility-seeking public policy, its underlying assumption of an armed force that delivers just one type of destruct limits its scope. While many military campaigns have been fought with primarily one type of destruct, especially those of an irregular, terrorist, special forces, air power, or anticipated nuclear-warfare nature, conventional land forces invariable deliver a variety of destructs, especially in this era of complex combined-arms actions. Therefore, how should the ROI equation (3) be modified to account for this?

The idea that the total benefit the state receives is a linear sum of the individual benefits each destruct generates might appear problematic. The argument that such linear thinking works better in a war of attrition, where the civilian constituents view each increment of enemy losses inflicted as an enhancement of their state's net gain in utility or benefits, might seem valid. Hannibal and Westmoreland employed this strategic assumption when killing Roman and communist Vietnamese troops, respectively. Such reasoning is especially applicable in conflicts where looting civilians, seizing financially lucrative territory, and capturing the enemy's military resources was the primary end goal—as early modern siege warfare demonstrated vividly. On the other hand, in a battle of annihilation involving complex combined-arms actions, the contribution of each individual destruct is highly non-linear, where the vast majority gets launched to deceive or constrain enemy forces to minimize the cost of launching the destructs that actually trigger the critical collapse of enemy resistance. For example, the destructs launched by mortars and assault rifles are often used to pin down enemy forces defending crucial targets, thus allowing them to be neutralized with a grenade at very low human cost to the attackers. Under such circumstances, the average attack-benefit function can be replaced with an aggregate-benefit function, a nonlinear function of the frequency of destructs delivered as well as their performance levels. From this perspective, a new profit objective function emerges in Eq. 12, where the cost and benefits of operating without new investments are ignored.

$$ROI = \frac{\mathrm{B}_t\left(z_1,\, z_2, \ldots z_n, q_1, q_2 \ldots q_n,\, A, M\right)}{\sum_{i=1}^{n} \mathrm{C}_i\left(z_i, q_i, D, P_i\right) q_i T_i + \left(A + M + D + P1 + P2 + \ldots + Pn\right)} - 1 \tag{12}$$

B_t is the aggregate attack benefit gained from the military campaign, and n is the total number of different destructs used to execute it. It is assumed that the design investment, D, is for the campaign in general, while the production investment, P_i, reflects the acquisition, training, and logistical investments associated with each individual destruct. The logic used is similar to that of a complex commercial product that comprises numerous subsystems or components, which represent distinct technological products in their own right. The attack-benefit function reflects the aggregate nonlinear combination of these individual components that the design effort achieves, while the production cost reflects a linear sum of their individual costs. For the sake of analytical simplicity, however, the discussion that follows of the individual independent variables and the dependent variables they shape will assume a military campaign involving selecting the optimum lethality and frequency level of a single destruct.

4. Technological Variables

A destruct typically involves a single discharge of a chemically powered projectile such as a bullet, shell, and bomb. Yet it can also involve a strike from a human-powered weapon such as a fist, bayonet, knife, and arrow. Electronic weapons are also included, such as computer viruses and electro-magnetic pulses. Non-lethal crowd control weapons generate destructs involving light (as in flash grenades), sound, stress, and heat. Finally, many peaceful commercial products can be easily used as destructs, ranging from matches to vehicles.[3] Al Qaeda demonstrated the power of jet airliners with full fuel tanks as weapons of mass destruction on 9-11.

A destruct can be delivered at a wide range of delivery or launch rates. Consider the firing rate of a muzzle-loading musket (up to three shots per minute) versus a Maxim machine gun (600 shots per minute); a heavy crank-operated crossbow (one shot every few minutes) versus a compound bow in the skilled hands of a mounted steppe warrior (a dozen shots per minute); a muzzle-loading cannon (two shots per minute) versus a 'quick firing' artillery piece with a hydraulic recoil system, such as the innovative French 75mm field gun of World War I (10 to 20 shots per minute).

Military commanders can change the delivery rate of destructs without changing weaponry. They can vary the number of soldiers deployed in a battle, change their training, provide more disciplined fire control, or enhance their logistical infrastructure and support. An eighteenth-century infantry company of 150 men armed with Brown Bess muskets could conceivably fire musket shots at the same rate as a single Maxim machine gun when expertly used. On the other hand, a brigade of 3000 British soldiers in 1905 could deliver small-arms destructs at a rate comparable to the entire British Army at the Battle of Waterloo (Keegan 2004, 248). Likewise, a tactical commander with limited ammunition supply rates has the option to stockpile it and then delivery it against an enemy force at very high rates but only for a restricted period, as demonstrated by the American defenders at both Bunker Hill and Little Round Top. For a military organization, consequently, the rate it delivers destructs to an enemy force is an independent variable.

The magnitude of a destruct's impact is another independent variable associated with technological performance. It may be measured by energy release, momentum transfer, stress, shock, biological toxicity, or electro-magnetic field strength. As documented by Papacino D'Antoni (1789, 202), an eight-pound artillery round shot fired at the supersonic speed of 1450 feet per second could obliterate a row of more than 20 horses. A one-ounce musket ball fired at a similar speed, however, could at best kill or wound one body. Similar contrasts could be made with a Model 24 *Stielhandgranate* versus the 4000 lb. "blockbuster" bomb of World War II, a small concealable dagger versus a heavy two-handled sword, or to use a more contemporary example, a Caracal-F 9mm automatic pistol versus a M107 0.50 caliber sniper rifle. The statistics that the Luftwaffe collected on the vulnerability of Allied bombers to the destructs launched by their fighter aircraft is also illustrative. While hundreds of regular 7.7 mm bullets were required to bring down a B-17, 20 hits with 20 mm rounds and only 3 hits from 30 mm exploding rounds achieved the same results.

Weapons delivering unimaginably high magnitudes of violence in a single 'blow' are certainly not just a feature of nuclear warfare. Giambelli designed his famous "infernal machine" or barge mine during the Siege of Antwerp in 1572 and launched it against the blockading pontoon bridge of the Spaniards. It carried such a heavy and well-directed charge that it not only destroyed the fortified structure, but also killed over 900 Spanish soldiers (Roland, 1978). The key issue for military organizations, however, is whether a

[3] I remain shocked by the magnitude of destruction I witnessed after George Weller crashed his car into the Santa Monica Farmer's Market on the Third Street Promenade on 16 July 2003.

generalized pattern or function exists between the rate of production, the magnitude of lethality delivered, and the average cost of producing and delivering such destruction to neutralize an enemy target. This is the central question for the supply-side perspective of military strategy.

5. Attack Costs

All forms of military destructs are associated with those direct or variable financial, material, and human costs that depend on their launch rate—unlike the indirect or fixed costs associated with investments. These include friendly combat deaths and physical injuries, as well as mental stress and psychological trauma. Such costs can be divided between those that are independent of combat-command decisions, such as acquisition and global logistics costs, and those that depend directly on them. The latter include whether to have combatants launch their destructs in open formations or in trenches, in a frontal assault or in a flanking attack, or through direct or indirect fire. As a result, a fundamental objective of a military force's hierarchical command and control system is to minimize the total attack costs to achieve a designated operational objective.

The financial costs of small-arms shots in a battle include the manufacturing cost of the bullets and propellant powder, along with the logistics costs of shipping them to a forward operating base and supplying them to individual combatants during an engagement. The maintenance and/or replacement cost of guns and firearms due to extended use may also be included in such accounting. The cost of delivering or shooting rounds also involves the expense of transporting, maintaining and commanding/controlling the individual soldiers who actually fire them. From an air-power perspective, the cost of dropping bombs involves the fuel and maintenance-costs to fly the bomber, expenses to maintain the crew, acquisition cost of the bombs, and various combat-support costs. The B-52 bomber, first flown in 1952, is currently scheduled to remain in service with the U.S. Air Force until 2040. Its longevity is primarily due to the relatively low unit costs of delivery aerial bombs at high delivery rates against weakly defended targets.[4] As with its industrial counterpart, the unit-production cost, the average cost of a destruct from a strictly material perspective directly depends on the rate it gets launched at enemy forces in a non-linear exponential manner, when all other independent variables are held constant. Such a phenomenon helps explain the seemingly irrational resistance in the U.S. Army's Ordnance Department during the American Civil War to breech-loading weapons that significantly increase the rate of fire relative to muzzleloaders. What caused such resistance to ultimately be overturned was the overwhelming political pressure to decrease friendly human costs that such an increased rate of fire permitted (Hallahan, 1994). Consequently, the friendly casualties or human loss that the soldiers risk must also be factored into the average delivery cost of the destructs they launch.

Soldiers delivering destructs to enemy forces in major urban operations generally risk far higher casualties given the enormous environmental complexities. They face

---

[4] For an analysis of the historical trend in the U.S. to maintain military aircraft of ever increasing age to minimize both acquisition investments and operation costs, see Ramey and Keating (2009).

both heavily fortified enemy combatants, who threaten to impose heavy average attack costs, along with the negative political externalities of injuring noncombatants and valued physical infrastructure (Glenn and Kingston, 2005). Therefore, the human cost of delivering destructs is highly dependent on both tactical and operational-command choices. As the Carthaginians under Hannibal demonstrated at the Battle of Cannae, a series of carefully planned maneuvers enabled them to deceive the Roman legions into becoming so severely compressed that most legionnaires could no longer wield their swords effectively. This had the effect of dramatically lowering the average human cost of the Carthaginians' destructs in terms of their sword trusts. In other words, they could strike down the boxed in Romans with very low risk of getting injured.

6. Supply-Side Investments.

Two fundamental military investment categories exist for lowering the unit-attack cost as a function of the destruct's lethality and frequency: tactical and operational. These are the military counterparts to the production and design investments of an industrial firm. The operational domain of a military campaign is the effort taken to achieve the desired strategic objectives by specifying and prioritizing particular enemy targets to be destroyed, captured or controlled. This could involve a particular building for a punitive aerial assault, or an armed force defending a highly strategic city. As the Soviets articulated with their Deep Battle doctrine, it could be a sophisticated analysis to identify the particular sequence of battles that must be fought to induce a systemic collapse of the targeted enemy force's resistance—as famously demonstrated during Operation Bagration in 1944. It could also involve the military-political system analysis coupled with explicit cost-benefit reasoning as seen in the Five Rings Theory (Warden, 1995). In short, the operational investment designs a military campaign in terms of targeting and timing to achieve the politically specified benefits for the least total cost.[5] It seeks not to enhance the political value of the campaign's achievement, however. That belongs to higher-level strategic analysis. The operational domain can be viewed as providing the campaign's blueprints that specify the specific combat or "production of destruction" missions. The tactical investment is therefore the military counterpart to the production investment. Once provided with the operational investment's campaign design, this investment involves both selecting and launching the necessary destructs to minimize the total combat costs of executing its missions.

Tactical investments from a technological perspective can be viewed as including four traditional military functions: lethality, protection, maneuverability, and command & control. The lethality side of the tactical investment is often associated with designing new weapons that deliver greater accuracy, launch rate, or lethality without increasing the average attack costs. A new loading mechanism that allows fewer gunners to operate an artillery piece is one example. A stronger gun barrel that generates greater muzzle velocities or a grenade with a greater blast radius could also represent a tactical investment from such an acquisitional perspective. These represent capital investments that decrease the function of the destruct's

[5] For a discussion of the relationship between design theory and operational planning, see Sweibelson (2012) and Elkus (2012).

unit-delivery cost in terms of delivery rate, and lethality level. Human-capital investments also exist, including training combatants in weapon safety, repair and maintenance, exercises to enhance combat and maneuvering capabilities. Advanced mathematical and scientific methodologies for officers and senior NCOs can also be included when it empowers them to maximize the lethality of each destruct they have launched, while also minimizing the number of missed shots. Lombard's analytically derived ballistics tables for the Gribeauval artillery system of late-eighteenth century France are a prime example of this (Steele, 2005). Likewise, Lavoisier's vast reorganization of France's gunpowder-production system to make it dependent only on secure domestic resources was also a tactical investment that dramatically reduced the average attack costs of French Revolutionary and Napoleonic armies (Mauskopf, 2005). Even the guillotine represented a tactical investment, not only from the executioner's perspective, but also when applied to enhance the combat aggressiveness of French generals during the Reign of Terror.

Tactical investments within the protection domain include both industrially produced and improvised armor for bodies, structures, and vehicles to neutralize projectile impacts or detonation waves. They also involve trenches and earthworks constructed by soldiers in the field to lower the launch costs of their destructs from a human-cost perspective. Technological innovations designed to increase the range of projectiles may also fall into the protection category, especially if they enable soldiers to deliver violence beyond the range of the enemy's ability to strike back. The active guidance system of smart bombs is an example of this. By increasing the height from which bombs may be dropped, this system increases the protection of bombers from surface-to-air destructs. A great deal of electronic warfare represents such a protection investment, as well. Jamming the radio signals that insurgents use to detonate an improvised explosive device or dropping chaff to direct anti-aircraft radar away from a targeted aircraft are prime examples. They specifically seek to lower both human and material dimensions of the unit-attack cost function without jeopardizing the frequency or magnitude of the destructs being delivered.

Efforts to enhance the maneuverability of a military force are also tactical investments. They help their soldiers launch their destructs from less vulnerable locations to obviate the need for protection investments. These investments help secure optimum range locations to neutralize targets for the least expenditure in lives, ammunition, fuel, and other factors comprising the average-attack cost. Maneuvering investments often ensure that enemy forces are caught off-guard and thus unable to organize effective resistance to drive up the average-attack cost of their attackers. Maneuvering investments certainly include aircraft, tanks and trucks, as well as surface and submarine vessels. They vastly increase the maneuvering capabilities of an armed force, albeit with average attack costs that include the cost of keeping it supplied with fuel. Hayward (1998) described how debilitating that price was for the Germans during the Stalingrad campaign. Their typically high maneuvering performance was limited catastrophically due to insufficient maneuvering investments in fuel trucks and transport aircraft. The innovative Soviet engineering of the 1930s, resulting in the Soviet Kharkiv model V-2 diesel engine, also shocked the Nazis when they first encountered it inside the T-34 tank as Operational Barbarossa commenced. It represented both a seemingly unachievable maneuvering and protection investment given its high power and reliability, as well as the low flammability of its diesel fuel. Yet even the relatively mundane combat boot and uniform designs that permit soldiers to march through extreme elements with less stress can also be categorized under the maneuvering investment. Strength and endurance training to enable heavily loaded soldiers to accelerate more rapidly can also be classed as the maneuvering investment. Such reasoning also applies to terrorism. Benmelech and Berrebi (2007) and Berrebi (2009) argue that the suicide bombers' formal educational achievements represented a maneuvering investment during the Palestinian Intifada from 2000 to 2005. They revealed a direct relationship between the bombers' ability to penetrate Israel defenses of high-value targets and their educational level. As a result, the militant Palestinian leadership reserved the most highly educated attackers for the targets of highest value to ensure a politically profitable outcome.

The investment category of command & control covers a host of material and human-capital options. Flags, standards, musical instruments, rockets and flares, and painted shields are a few of the technological investments pre-modern armies used to enhance the ability of commanders to exercise control of their military units. The expansion of an army's hierarchy of command and the formal mathematical education of military officers are examples of such investments associated with the Military Revolution of early modern Europe (Eltis, 1995). Scharnhorst's insistence after the calamity of Jena-Auerstadt to start educating Prussian junior officers on how to think strategically and take initiative, as a general officer would, also represented a command & control investment (White, 1988). The idea was to maintain effective military initiative even when a catastrophic breakdown in formal command communication occurred, as well as minimize the hierarchical flow of information up and down the chain of command under normal circumstances. Many other tactical investment categories exist, including information warfare to lessen the military resistance of enemy troops or compel local civilians to cooperate with intelligence and logistical support units. Humanitarian relief can also represent a tactical investment by mitigating local civilian hostility and inducing greater cooperation, thus generating a host of strategic dilemmas for non-government organizations (NGO) that provide such services (Lischer, 2007). Propaganda designed to stimulate recruitment of military personnel or undercut political resistance to compulsory service, as demonstrated by Flagg's famous "I Want You" poster of Uncle Sam during World War I, can also be viewed as a supply-side tactical investment.

Operational investments involve the effort to design military campaigns to achieve a designated political objective. They include selecting tactical objectives or combat missions, and scheduling the timing of their execution. As with the tactical investment, this involves both material acquisitions as well as research, analysis, and design synthesis. Examples include the U.S. Army Air Corps' study of the modern industrial economy's vulnerabilities to determine "critical nodes" for targeting (Johnson, 2000). They also range from the high priority placed by the navies of World War II to sink enemy oil tankers, and Napoleon's concentration on annihilating enemy armies instead of capturing strategic fortresses and cities—at least until his 1812 invasion of Russia. A more recent example is the US decision to prioritize the overthrow of Saddam Hussein's regime in Baghdad over securing captured weapon depots and maintaining law and order in occupied territory. The Pakistan Army's decision in 1999 to infiltrate and defend the high-altitude ridges overlooking National Highway ID in Kargil is another example. From this perspective, Boyd's maneuver warfare theory, associated with the "OODA loop," is an operational investment, given how it only provides supply-side guidance on prioritizing and scheduling the destruction of enemy military forces to maximize their systemic entropy (Osinga, 2007). The Air-Land Battle doctrine is also an operational investment from this supply-side perspective. It seeks to select targets carefully to induce the systemic disruption of a given military force, especially when its components stretch across a vast geography—such as the anticipated Soviet offensive through the Fulda Gap during the Cold War (Naveh, 2007). An operational investment may also involve deciding which enemy armed force should be defeated first to minimize overall campaign costs. In this sense, the study of Earl Ellis of the U.S. Marine Corps during the 1920s was a brilliant operational investment. He concluded that capturing key fortified islands from the Japanese must be prioritized over inflicting a single Mahanian-style battle of annihilation against its fleet (Steele, 2005 b).

Nathaniel Greene's decisive campaign to recapture North and South Carolina from the British army of Lord Cornwallis also helps clarify the difference between the operational and tactical investment domains. The basic strategic goal of targeting the British army was never in doubt. General Washington and the Continental Congress established this from the beginning. The genius of Greene therefore lay not in maneuvering Cornwallis into a battle of annihilation where he could deliver a superior rate of destructs in terms of musket fire, as other American commanders accomplished at the Battles of Kings Mountain and Cowpens. Instead Greene had the profound operational insight that he could dramatically increase the costs of Cornwallis' logistical system by inducing him to make many exhaustive marches that far outpaced its intended capabilities (Haw, 2005). Due to funding limitations, its performance consequently became disastrously inadequate. Thus when Cornwallis won a tactical victory over Greene at Guilford Courthouse, his forces delivered insufficient destruct launch rates to annihilate the American forces as at the earlier Battle of Camden, thus allowing them to retreat south to retake North Carolina with relatively few losses. Cornwallis elected instead to make a major operational decision and take his severely weakened army to invade Virginia, with catastrophic consequences at Yorktown. Such battle-losing/war-winning revolutionary-war strategy, which also captivated Mao and Giap, stands in contrast with the popularity of military production functions that viewed battlefield victory as the primary output of an armed force (Hayward, 1968; Rotte and Schmidt, 2002). In their defense, however, Giap, that former history teacher, clearly viewed Dien Bien Phu as his decisive Yorktown-style siege.

Moreover, Grant and Sherman displayed the most innovative operational reasoning during the U.S. Civil War. They realized that by having Sherman's Army of Georgia target the strategic infrastructure of Georgia and South Carolina without secure lines of communication, they could devastate the logistical support for the Army of Northern Virginia under Lee (the Confederate's "center of gravity" to use Clausewitz's mechanistic expression) far more effectively than by attacking the Confederate Army of the Tennessee under Hood (Smith, 1997). This operational decision had the additional value of enabling Sherman to impose devastating economic losses on hundreds of thousands of Confederate civilians to erode the demand-side investments of the Confederate government.

Operational investments are traditionally the focus of senior military staff and intelligence officers who collect the data and generate analysis that senior commanders and their political masters require to design effective campaigns. When designing his campaigns, Napoleon nevertheless spent months buried in archival material to acquire vast amount of detailed geographical, economic, political, and biographical information about the targeted enemy state. The Mongol leaders who rapidly conquered much of Asia in the Thirteen Century made similar operational investments in accordance to Sun Tzu's command to "know your enemy." On the other hand, the concept of the "strategic corporal" reflects how non-commissioned officers may be forced to make sudden operational decisions in the complex combat environments of counterinsurgency warfare. For example, should he aid a wounded civilian or chase after the retreating insurgent? Understanding the vast investment implications of even seemingly trivial combat decisions is therefore an urgent educational requirement even for privates to help them grasp the logic of seemingly counterintuitive "rules of engagement."

The financial magnitude of operational investments has increased dramatically during the 20th century, especially from a technological perspective. Whole industries have now emerged that now provide the means to enhance operational capabilities. These include data processing, geo-spatial imaging, satellite surveillance, cryptography, computer hacking, and intercepting telecommunication messages. It is noteworthy, however, that such technological achievements, cannot replace educational investments to enhance basic critical and strategic reasoning. The vast operational investments supporting the US Forces when invading Iraq in 2003 could not compensate for almost all of their senior officers' studious ignorance of the basic maxims of counter-insurgency theory. The key operational idea of that theory, as developed famously by David Galula, is that the primary objective is not the destruction of the insurgent force. It is instead to gain the political support of the local civilian population (Galula, 1964). Reducing the destruction of enemy armed forces to a secondary consideration was well articulated by Mao in his writings on revolutionary war and demonstrated masterfully by the Prophet Mohammed (PBUH) in his military campaign against Mecca (Gabriel, 2007). After extensive economic warfare against Mecca by targeting its caravans, he finally won over the business interests of that city by promising to maintain the Kaaba as a financially lucrative site of pilgrimages and prohibiting his Muslim soldiers from harming the city. The resulting political support he subsequently gained ensured that the physical resistance of the defending army rapidly evaporated and Mecca capitulated with few casualties.

7. Average Attack-Cost Function.

The issue of the average attack cost will now be considered. For a given lethality level and launch rate of a destruct, what is the minimum average attack-cost, $C(z, q)$ that an armed force can achieve when subject to fixed levels of investment? As demonstrated in Steele

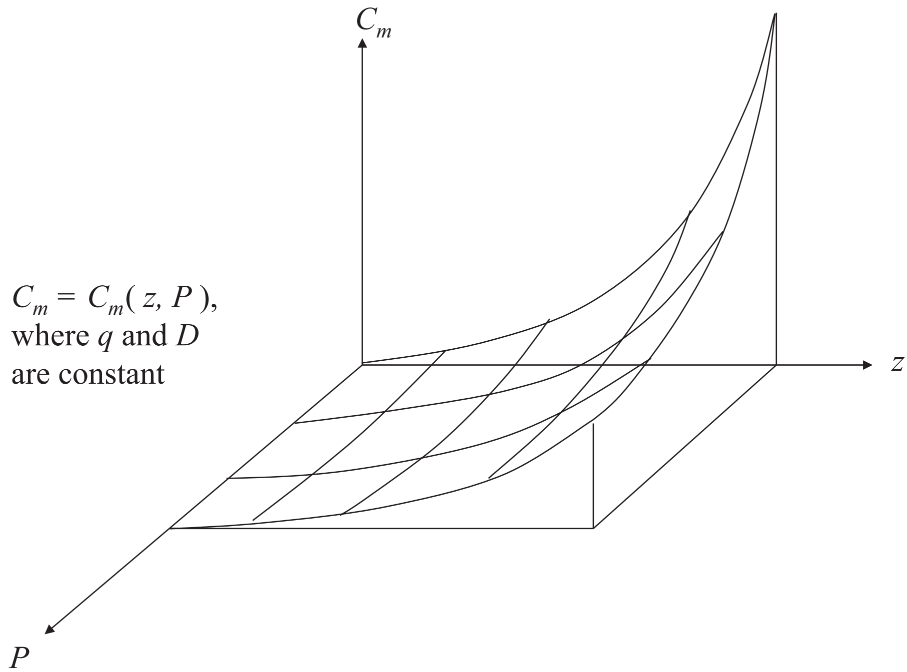

Figure 1: Average material attack cost, C_m, as a funcion of destruct performance level, z, and tactical investment, P.

(1995 and 2013), the resulting C(z, q) model of an industrial firm's production capabilities can be represented with exponential functions. To apply such reasoning to the military domain, first consider the relationship between the material side of the unit- or average-attack cost, C_m, and destruct performance level, z, for a fixed level of tactical investment, P.

In this scenario, the average attack costs rises exponentially as the destruct's lethality level delivered increases, relying on the same physical reasoning for the performance function of a commercially engineered product. This can be justified by considering the material costs associated with artillery fire. For a fixed investment, one can purchase a lightweight artillery piece to fire a small projectile that delivers relatively low levels of destructive kinetic energy. Such low weight, however, translates into considerable average attack-cost savings in terms of the number of soldiers required to service the gun, the quantity of propellant required to accelerate the projectile, and the logistics costs to transport the ammunition to the gunnery crew. If one wishes to increase the lethality-performance level of the projectile, z, either by increasing the projectile's muzzle velocity, increasing its mass, increasing its explosive charge or even increasing its kinetic impact energy by decreasing its range, the average attack cost of shooting the projectile will increase. Since investment funds are fixed, a heavier and therefore more expensive gun barrel will be required to shoot the more lethal projectile safely. However, such a greater investment in the gun's hardware means that other tactical investments must be curtailed, such as gunnery instruments or live-fire exercises. As a result, the accuracy of the heavier rounds fired declines, thus requiring more rounds to be expended in order to neutralize the desired

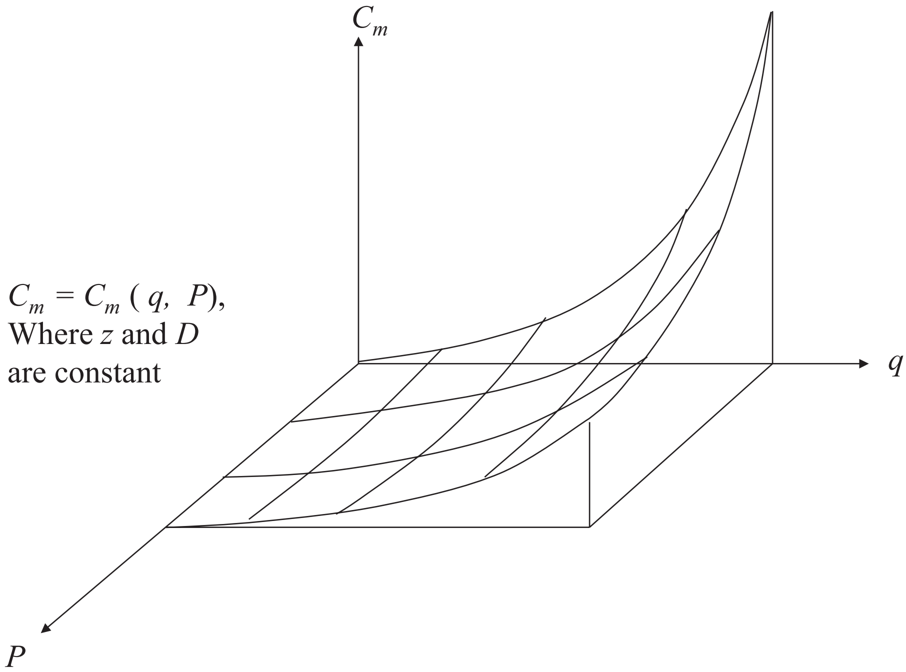

Figure 2: Average material attack cost, C_m, as a funcion of destruct performance level, q, and tactical investment, P.

target. Thus as the performance level, z, of the projectile increases, the average attack cost increases exponentially. Greater investment levels offer the means to decrease such a function. Thus, as shown in Fig 1, greater investment levels can generate greater levels of destruct performance for a fixed average-attack cost, or can lead to ever decreasing unit-violence production costs for a fixed destruct-performance level. In other words, whether one deals with the production of a commercial product or military destruction, the same mathematical function can be used to model $C_m(z)$. Yet, does the same reasoning apply to average-attack cost as a function of destruct-launch rate, $C_m(q)$?

Increasing the launch rate of destructs when the investments are held constant also leads to an exponential increase in unit cost, as shown in Fig. 2, using the same diminishing marginal-product reasoning for a commercial product in Steele (1995 and 2013). As this frequency increases, larger portions of the tactical investment must be used to increase the acceleration of transporting and launching the destructs, relative to the portion seeking to decrease its cost. Take for example the loading, aiming, and firing of an artillery piece. Increasing the rate of fire for a fixed level of investment can be achieved by employing more skilled and coordinated gunners. However, the increased training investment required must be offset by decreasing another investment, such as the cost of using more expensive metal to minimize the weight of the barrel. A heavier barrel, however, imposes greater preparation and maintenance costs on the gunners, which directly increases the average cost of firing a shell. Adding more soldiers to the gun crew might increase the launch rate, but that too will add to the unit cost of firing a single shell in terms of employing, sustaining, and protecting them. Increases in the tactical investment level from a lethality perspective, such as adding an automatic loader to the gun or a proximity fuse to the shell, could potentially lower the average attack cost. Providing faster trucks or transport aircraft to increase the rate that shells get delivered to the front lines could also lower it. Sandbags placed around the artillery piece, a tactical investment from a protection perspective, also can lower the average material cost of launching destructs, for a given firing rate, because it lowers the risk of having the weapon systems knocked out from counter-battery fire. In short, C_m (z, q, P) is a fundamental representation of the tactical capability of a military organization from combat, logistical, and acquisitional perspectives. Like its industrial counterpart, this average attack-cost function reveals how well a military organization can minimize its material costs for given levels of the destruct's performance level and launch rate for a fixed tactical investment—within the context of a particular campaign.

Unlike its counterpart in a presumably Kantian commercial domain, human costs invariably represent a significant dimension of average attack costs and must be formally considered. When a military force seeks to launch destructs against an actively resisting enemy force, the human losses or casualties it endures inversely depend on both the attack rate with which it delivers destructs, as well as lethality performance levels of the destructs. At very low levels of attack rate, q, the average human cost, C_h, is initially relatively high, given the enemy force's ability to resist with superior rates of destruct launches. As one's delivery rate increases, however, such human losses decline as superior "firepower" is gradually brought to bear against them.

The Battle of Little Big Horn in 1876 vividly demonstrates the consequence of a military force entering into combat with relatively low levels of attack rates. Custer's troops were armed only with single-shot Springfield carbines and single-action Colt revolvers, coupled with poor marksmanship training and weak fire-control management. In a classic tradeoff decision between lethality and mobility, Custer left behind his Gatling Guns to increase his mobility. As a result, the superior numbers of Lakota, Arapaho, and Northern Cheyenne warriors, who suffered relatively few casualties, quickly annihilated his force primarily with high frequency, long-range fire—thanks to the brilliant tactical reasoning of Chief Gall. Their arms included state-of-the-art repeating Henry and Winchester rifles, along with obsolete muzzleloaders (Hallahan, 1994). Many US soldiers armed with semi-automatic M-14 rifles in the initial stage of the Vietnam War experienced similar disadvantage when facing NVA and Viet-Cong troops armed with fully automatic AK-47 assault rifles (Ezell, 1984).

The smoothbore musket remained the principle infantry firearm well into the nineteenth century precisely because of its higher firing rate relative to longer-range rifles—that is until the Minié ball innovation eliminated that advantage. Another example is the sizeable tactical advantage Union cavalry forces started to enjoy over their Confederate counterparts once the bureaucratic opposition to repeating carbines in the US Ordnance Corps was overcome. As demonstrated by the German *Sturmtruppen* during their Spring 1918 offensive, the ability to impose superior launch rates is a significant means to impose psychological shock on enemy troops, a condition that leads to their inability to resist even

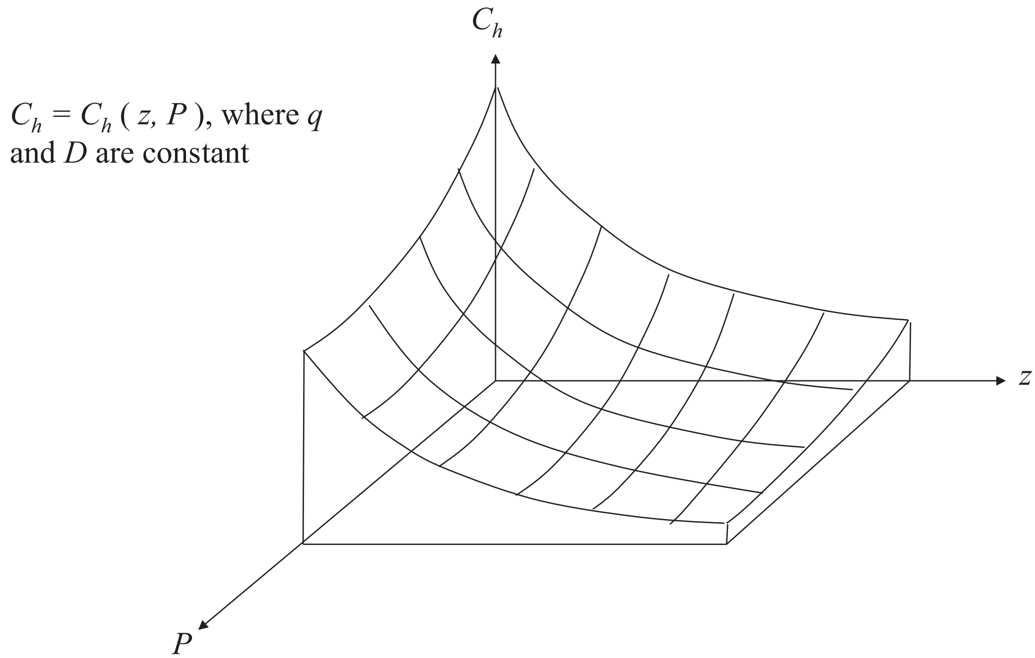

Figure 3: Average human attack cost, C_h, as a funcion of destruct performance level, z, and tactical investment, P.

with sufficient cover to physically protect themselves (Biddle, 2004). The Indian forces demonstrated this when assaulting the entrenched high-altitude positions of the Pakistani troops during the Kargil War. During the Battles of Tiger Hill and Tololing, the Indians launched vastly superior rates of artillery and small-arms fire to overcome the tough Pakistani defenders at politically acceptable human costs.

Such tactical reasoning can also be applied to lethality levels. As the destructs are delivered with greater lethality levels, holding all other independent variables constant, the lower the human costs. The heavy casualties the American forces endured during the Battle of San Juan Hill, where the Spanish defenders inflicted over five times the casualties they received, reflected the more powerful Mauser rifle shots they fired relative to what Americans could respond with their Krag-Jorgensen rifles. The Mauser's rate of fire was also superior given its higher reloading speed.

Based on such historical and logical perspectives, one can model quantitatively the relationship between friendly human cost, C_h, as a function of attack rate, q, and lethality level, z. As shown in Fig. 3, $C_h(z)$ is a downward sloping function that models the tendency of a force armed with increasingly heavier or more lethal weapons to enjoy increasingly fewer casualties when resisting an enemy force with constant capabilities. This is due to the greater casualties it can generally inflict on that force over the same period of time, thus reducing the enemy's destruct launch rate. As with other supply-side investments, tactical investments can push down the $C_h(z)$ function by offering more capable weapon designs, as well as more effective combat tactics and logistical support. Patton paraphrased Vegetius on the inverse relationship between the military-training investment and human

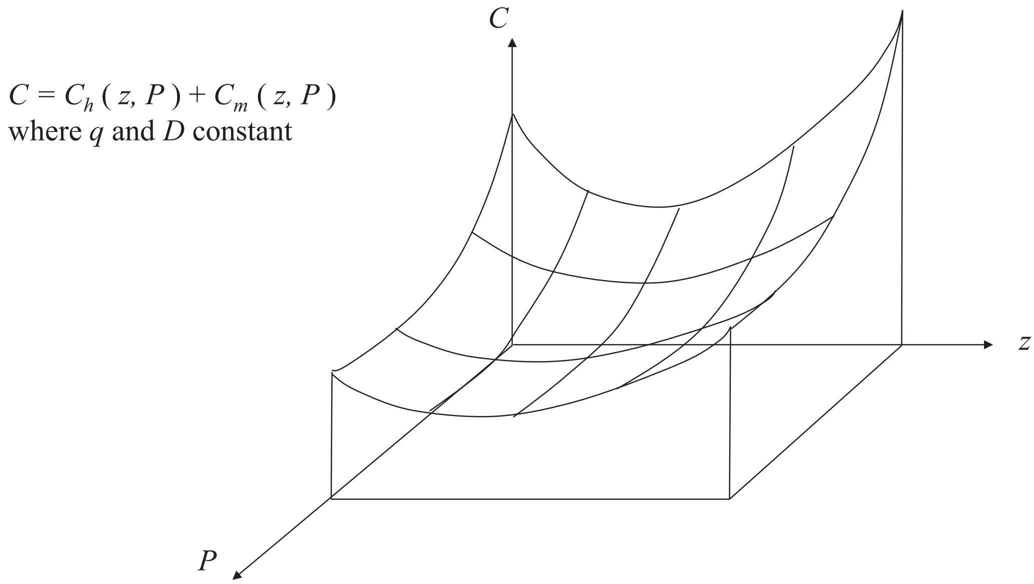

Figure 4: Total average attack cost, C, as a funcion of destruct performance level, z, and tactical investment, P.

costs when he said, "the more you sweat in peace the less you bleed in war." A more recent example includes the American use of UAVs to attack Taliban targets in the tribal regions of Pakistan. Such an investment offers a vast reduction in human-attack costs to the U.S. Special Forces, who might otherwise execute these missions, albeit at the politically damaging cost of increased civilian deaths or "collateral damage." The same downward sloping curve in Fig. 3 can be used to model $C_h(q)$, the average or unit human attack cost, as a function of launch rate. As a military force increases its rate of fire, or destruct delivery, it will suffer from fewer casualties for a given tactical investment level. Again, the Battle of Little Big Horn, as well as the Ottoman defense of Plevna the following year, exemplifies this (Hallahan, 1994).

By combining the C_m and C_h functions, a more complete average attack-cost function, as modeled in Fig. 4, can be generated. Combining such seemingly incommensurate quantities as material and human costs is obviously disturbing. How can the life of a single teenage recruit be compared to some boxes of ammunition, barrels of gasoline or fox holes? Yet the harsh reality is that making such human-versus-material tradeoff decisions is a fundamental requirement for both operational and tactical military leadership, as Erich von Manstein demonstrated repeatedly in his vociferous arguments with Hitler in 1944. Combatant commanders must routinely decide how to allocate their human and material resources, including those they can expend in combat within the immediate political limits. As Grant experienced after the Battle of Shiloh in 1862, the political repercussions of miscalculation can be severe. Beyond the political cost that grieving families of fallen soldiers represent to their states, the dead and wounded generate tangible financial costs that must be considered when making basic strategic assessments, including evacuation costs, medical treatment, pensions, and even mortuary services—as the unburied fatalities at Borodino and Waterloo suggest. By examining Fig. 4, the relationship between the minimum total cost that a military system can achieve and the destruct's lethality levels and tactical investment levels, $C(z, P)$ can be observed. A similar relationship may also be used to model $C(q, P)$ for a given destruct, thus revealing the minimum average attack cost for a given destruct-delivery rate and tactical-investment level. What then should be the optimum level of the independent variables of tactical investment, P, the destruct's lethality level, z, and delivery rate, q? As in the commercial domain, such a question can only be answered with a broader ROI function that considers both the supply-side and demand-side functions.

8. Demand-Side Variables

If a military system endures significant human and material costs when delivering destructs to enemy forces, what then are the compensating benefits its executive leadership seeks? What is the relationship between military performance and attack benefits, as represented in the commercial context with the sales-price function? Likewise, how does this attack-benefit function relate to such demand-side investments as marketing and advertising? To address these questions, two types of military organizations must be considered: privately owned or "irregular" terrorist, insurgent, and militia organizations versus state-owned "conventional" military forces. For the former, the expense of the violence inflicted must directly generate material, human, and/or financial gains if the organization is self-sustaining or seeks to grow in strength. This is the fundamental strategic requirement for a successful insurgency campaign, as demonstrated by the Prophet Mohammed (PBUH) and articulated in the 1930s by Mao (Gabriel, 2007). For an insurgent or irregular force, every IED it explodes, every suicide bomber it sacrifices, or every airplane it hijacks must get translated into a compensating benefit that it can tangibly leverage into assets to compensate for such costs, which include the losses resulting from the government response.[6] Otherwise, resource bankruptcy and tactical impotence results. The never-ending mutinies and insurgencies in the eastern provinces of the Democratic Republic of Congo exemplify this, with its rich deposits of coltan and other valued commodities that rebel commanders, (and neighboring states) are willing to invest their military resources to mine and export (Montague, 2002).

Early modern European military commanders often acted like armed non-state actors. They were heavily dependent on the resources secured through taxing the local populations under their occupation. Wallenstein, the Habsburg military commander of the Thirty Years' War, was especially successful with his entrepreneurial means to acquire such "contributions" (Redlich, 1959). The military leaders of modern state-sponsored military forces, on the other hand, are generally prohibited from pursuing the self-sustaining *bellum se ipsum alet* military strategies of armed non-state actors. They instead focus on how to

[6] As noted by Neumann and Smith (2005, 589): "The dilemma here is that, while the terrorists need to elicit an inefficient act of repression that will highlight the 'unjust' nature of the regime, any belligerent that faces a militarily more potent adversary has to take extreme care not to push the enemy into a corner to a point where it feels sufficiently desperate to escalate the war to a level at which repression becomes ruthless and total, thus threatening the terrorist group's very existence."

design campaigns and execute combat missions to achieve politically authorized objectives with only politically authorized resources. However, when even a civilian commander-in-chief fails to maintain such a constitutional constraint, as President Reagan demonstrated during the Iran-Contra scandal, the political consequences can be severe.

The strategic-thinking responsibilities of modern state-sponsored military forces are thus divided between the political authorities who secure the financial means to fund the military campaign and the military authorities who use those funds to imposes costs on enemy societies to extract the benefits specified by these political authorities. In contrast, the strategic thinking within the leadership of terrorist, insurgent or even militant criminal organizations must combine both dimensions. They must simultaneously consider both the demand-side reasoning of political authorities and supply-side reasoning of military commanders because they are responsible for their own funding. Nevertheless, the basic utility function of both conventional forces and armed non-state actors remains the same. Both forces seek to deliver destructs in order to secure desired benefits. The key difference is that for armed non-state actors, these benefits must be of a tangible nature that makes up for the costs of the destructs. For conventional forces, the benefits may be far more intangible—provided the bill-paying political authorities and their tax-paying constituents perceive the exchange to be satisfactory.

9. The Average Attack-Benefit Function

The anticipated benefits achieved by military forces could include captured territory, secured strategic resources, or protected physical infrastructure, as well as higher levels of civilian political support, economic growth, or international political cooperation. Regardless of whether the resources are secured from the enemy state or domestic political constituents, its magnitude depends directly on the performance level and frequency of the destructs being launched. Depending on the depth of enemy defenses, the morale of their troops, the physical terrain, and weather, as well as numerous other factors, this average attack-benefit function can vary significantly. The Turkish infantry forces willingness to deliver high rates of accurate Mauser and Maxim gun fire against Allied troops during the Battle of Gallipoli, while enduring heavy casualties, was directly related to the vast political benefits their government and allies enjoyed by maintaining control over the Dardanelles and the city of Istanbul. Nevertheless, the Ottoman Empire's failure to maintain such performance in the Levant ultimately led to its dismemberment in the Treaty of Versailles. Likewise, the French army deployed the mobile batteries of the quick-firing 75 mm field gun, under the command of elite École Polytechnique graduates during the First Battle of the Marne. They poured shells accurately and rapidly into open formations of German infantry units with devastating effect. Such high performance was directly related to the vast political benefits the French government enjoyed by reversing the German invasion and forcing a retreat. Nevertheless, the Allied force's inability to sustain such performance prevented a full reversal of the invasion and years of trench warfare on French territory resulted. In short, the frequency of destructs an armed force can deliver in a war is directly related to the magnitude of political benefits its state can achieve.

The benefits gained by imposing losses on enemy forces are also related to the lethality levels of the destructs being delivered. Increasing the caliber of pistols used against the Moro tribesmen during the Philippine-American War significantly aided their disarmament by U.S. forces. Sénarmout demonstrated at the Battle of Friedland in 1807 that by increasing the kinetic energy of his smoothbore artillery projectiles by maneuvering their guns ever closer to massed Russian troops, he magnified the political concessions Napoleon received from the Czar in the Treaty of Tilsit. Similar reasoning during the early modern era could be applied to heavy 32-pound siege guns versus lighter field guns. When fired at point-blank range, the former could readily demolish the curtain walls of fortresses, which were otherwise impervious to lighter round—a harsh reality Napoleon faced during the Siege of Acre after the British captured his heavy siege artillery. Hannibal endured similar frustration when facing the fortifications of Rome without heavy siege machinery. A more contemporary example involves the lightweight explosively formed penetrators (EFPs) that deliver hypersonic terminal velocities. They can cut through the armor of heavy combat vehicles, such as the M-1 tank, that are impervious to slower yet heavier anti-tank rounds. Such highly lethal attacks offered correspondingly high benefits for the Iraqi insurgents when fighting the U.S. forces. Given the value of these vehicles as symbols of American military power, their destruction translated directly into substantial cash payments from their political clients, especially when their destruction was videotaped. From this perspective, Murphy and White (2007, 23) concluded, “Their impact is not the tactical kinetic victory but the strategic propaganda victory.”

With such historical and mechanical perspectives in mind, it can be deduced that the average attack benefit function is directly related to both the magnitude and frequency of destruct being delivered, or $S = S(z, q)$. Unlike the average attack-cost function, however, $S(z)$ and $S(q)$ do not increase exponentially. These demand-side functions initially are subject to a horizontal asymptote before turning downward not unlike a ballistic trajectory,

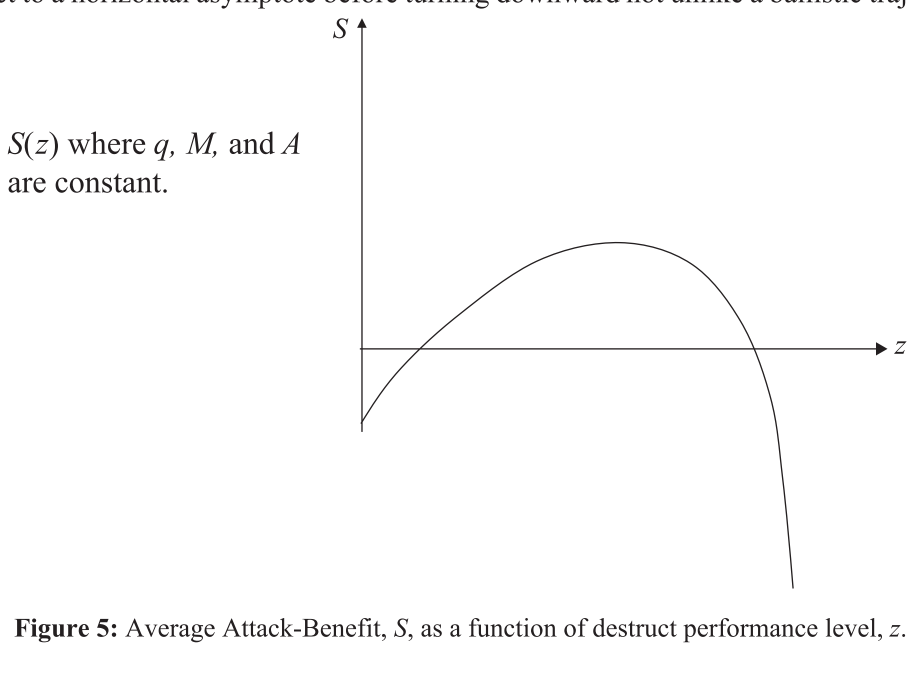

Figure 5: Average Attack-Benefit, *S*, as a function of destruct performance level, *z*.

as described in Fig. 5, to reflect the counter-productive consequences of excessive military destruction. This average attack-benefit function also differs from the unit sale-price function of a commercial firm since it commences in the negative domain. Insufficient levels of a destructs lethality lead to tactical military defeat and the resulting transfer of valued political or economic assets to the enemy state.

Once sufficient levels of destruct performance are achieved to secure positive benefits, greater increases lead to diminishing marginal benefits as the slope starts to decrease. This can reflect the growing negative consequences such as destroyed civilian lives and infrastructure, hardening of enemy resolve, or rising domestic and international political opposition. Eventually, such negative consequences begin to outweigh the positive, as represented by the negative slope of the average attack-benefit function.

As the Japanese discovered after Pearl Harbor, the French learned during the Algerian War of Independence, President Kennedy feared during the Cuban Missile Crisis, the West Pakistanis experienced in East Pakistan during Operation Searchlight, and the Americans endured immediately after capturing Baghdad, excessive levels of destruction can rapidly decrease the net gains sought. Such strategic reasoning was also reflected in Marshall Vauban's siege warfare policy during the Wars of Louis XIV of never targeting the civilian infrastructure of a besieged town. Instead, he carefully directed his gunfire on only those military bastions and curtain walls required to compel a capitulation. In addition to minimizing his cost of ammunition and soldiers' lives, it also maximized the captured city's strategic value. The counterproductive political consequences Frederick the Great experienced after his terror bombardment of Dresden in 1760 stands in stark contrast. Such fear of the negative consequences of increasing the magnitude of violence also constrained both Truman and Johnson during the Korean and Vietnam Wars, respectively, much to the chagrin of glory-obsessed military commanders like Douglas MacArthur with his "no substitute for victory" rhetoric.[7]

On a smaller scale, the heavy 0.50 caliber sniper bullet can be hazardous from the demand-side perspective precisely because it could penetrate the intended enemy body and then continue penetrating into the politically sensitive body of an innocent civilian or friendly comrade in another room. For this reason, relatively lightweight shot cartridges are generally preferable to heavier rifle rounds for home defense. The gut-wrenching photograph of the screaming 9-year old Kim Phuc with severe napalm burns played a substantial role in turning American public opinion against the Vietnam War. It represents a sober example of how easily the average attack-benefit function can plunge into the negative benefit domain, especially when chemical weapons are involved—as the Assad regime of Syria recently discovered. On a broader scale, the U.S. Army faced severe difficulties in attempting to incorporate tactical nuclear weapons in their defensive plans for Western Europe during the mid-1950s, associated with the innovative yet short-lived Pentomic Division. Its leaders discovered how quickly one reaches the negative depths of the average attack-benefit function in nuclear warfare (Bracevitch, 1986).

[7] Perhaps this reflects how institutionally warping it was for the U.S. Army to fight the strategically incompetent yet tactically brilliant German and Japanese forces during World War II.

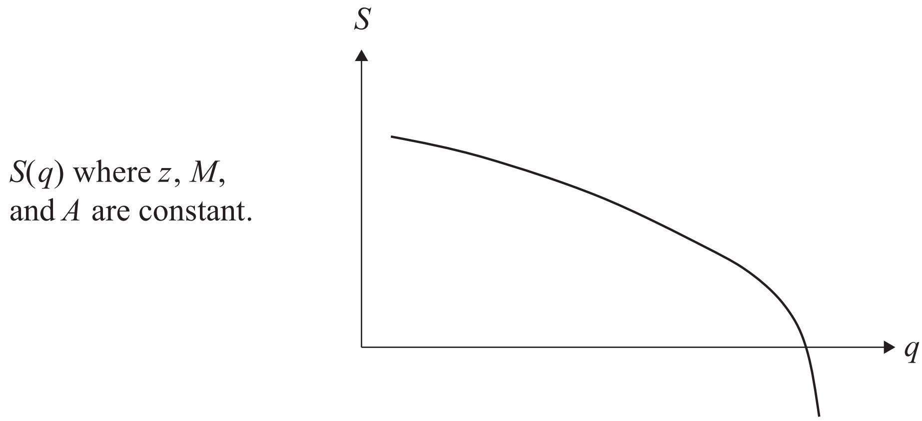

Figure 6: Average Attack-Benefit, *S*, as a funcion of destruct delivery rate, *q*.

Similar arguments can be made for increasing the frequency of launching destructs. Beyond a certain point, there are no longer any beneficial losses to impose on enemy forces. The destructs are "bouncing rubble" at best and destroying prized political support at worst.[8] The heavy civilian losses resulting from the fire-bombing of Heilbronn in December 1944 hardly encouraged those Württenbergers to welcome the advancing American forces as liberators from catastrophic Nazi tyranny in April 1945. Instead, it helped fuel the fanatical "last-ditch" defense of that city, especially from the local *Volkssturm* or militia units (Longacre, 2011).

Why then is the average attack-benefit function, S(q), as shown in Fig 6, always downward sloping? This occurs because increasing numbers of progressively lower-value targets need to be selected as the frequency of destruct launches increase. As explained in a nuclear warfare context by Hoag (1967, 10), "As the operational planner moves beyond the obvious assignments of at least one missile to each of a few key cities, he will face diminishing returns for each additional missile that is assigned." In other words, the average attack-benefit decreases as the launch rate increases. Such reasoning conforms to the microeconomic logic of the downward-sloping demand function in the commercial domain. Unlike the concave demand function, however, the military-demand function appears to be more convex to reflect the vastly different physical conditions and social objectives. Nevertheless, the total-attack benefit as a function of destruct frequency does peak at a particular level, like the S(z) function in Fig. 5. It is the product of the average-attack benefit, S, launch rate, q, and campaign life cycle, T.

10. Demand-Side Investments

What types of investments can increase the average attack-benefit function, S(z)? More specifically, what can a military system do to ensure that a given military campaign

---

[8] See chapter six in (Brauer and Van Tuyll 2008) "The Age of World Wars, 1914-1945: The Case of Diminishing Marginal Returns to the Strategic Bombing of Germany in World War II." As seen on p. 202, they focus only on the upwardly sloping portion of this "input-output" military function.

generates the desired perceived benefit for particular levels of launch rate and performance? What ensures that when a designated target is destroyed, the constituent citizens perceive that satisfactory progress is occurring towards the political objective, such as unconditional surrender, recognition of independence, trade concessions, regime change, or in especially brutal conflicts: slaves, loot, ethnic cleansing, and mass executions? The same investments categories that shape the unit-sales price function of a commercial product also apply to the average attack-benefit function of a military organization: marketing and advertising.

Before discussing the military counterpart of marketing and advertising, an important distinction needs to be expressed. If the "customer" is defined as the agent from whom one seeks resources in exchange for a technological product or destruct, then the leader of a military system at war faces two categories of customers. The first is the enemy state. It gets assaulted with destructs to convince its leaders to hand over the resources demanded, not unlike a customer who receives a commercial product is compelled to hand over the sales-price funds. Both scenarios involve an exchange, however coercive the former may be. The second category of customer is the constituent population or citizens of the state. Its leaders may opt to pursue a war to secure such politically desirable resources as greater acquiescence to their political authority in terms of election-winning votes or mitigation of political opposition. The Argentinian junta's invasion of the Falkland Islands in 1982 and the numerous counter-terrorism strikes of the Israelis are prime examples of this. Johnson's decision to escalate the war in Vietnam was primarily motivated to avoid the severe McCarthyism hysteria that besieged the Truman Administration for "losing China," and threatened to jeopardize his monumental domestic agenda. After all, South Vietnam by itself represented little strategic value to the US—hence the marketing investment that deployed Eisenhower's "Domino Theory" and the "Credibility Argument" during the Vietnam War (Cuddy, 2003).

Marketing is assumed to involve the process of designing a sales argument that seeks to boost the perceived value of a commercial product in the minds of the customer. Based on both social and technological research, it can provide extremely objective technical descriptions to educate potential customers about the specific performance levels being delivered. The engineering-oriented advertisements of the early Ford Motor Company, which emphasized the superiority of specific components, were paragons of such an approach. The psychologically sophisticated advertisements of General Motors during the 1920s stands in direct contrast. The automobile in question was presented only as a means to such desirable ends as sexual attractiveness, urbane sophistication, or shear hedonistic pleasure. Both marketing approaches attempt, however, to enhance the perceived value of the product in the eyes of the potential customer.

Wartime propaganda for a domestic audience serves the same basic function. It too represents an investment in designing an argument that enhances the perceived value of the destructs being launched in a war or military conflict. The invocation of the "9-11… never again" mantra by Presidents Bush to justify the wars in Iraq and Afghanistan represents a relatively inexpensive propaganda or "marketing" investment, especially when compared to the complex ideological justifications of the Neocons in his administration. Similarly,

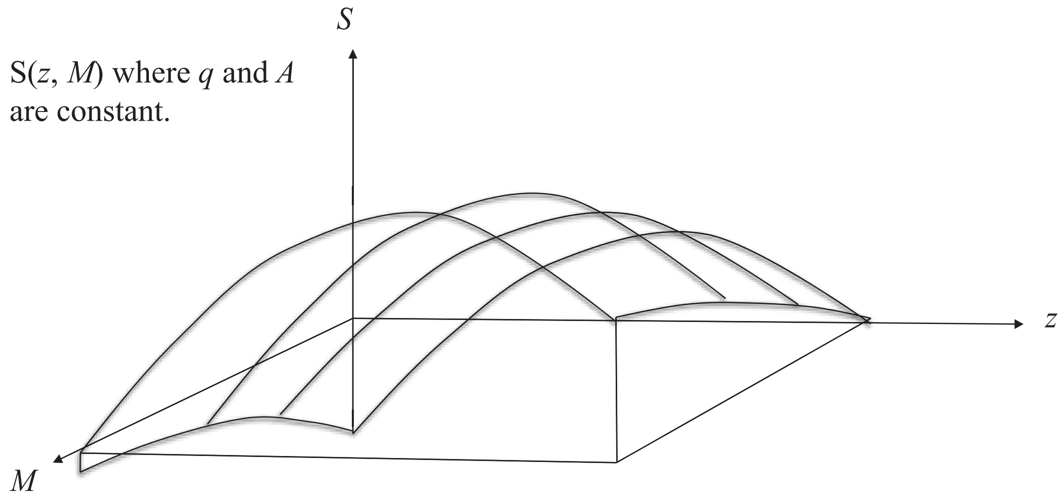

Figure 7: Average Attack-Benefit, S, as a function of destruct performance level, z, and marketing investment, M.

the Ayatollah Khomeini took decades to develop his Plato-inspired theocratic ideology used to justify the numerous sanguinary offenses against Iraq during the Iran-Iraq War. The relatively straightforward anti-colonial and French-Revolution inspired propaganda of the Viet-Minh and the Algerian FLN used to justify fighting the French stands in contrast to the enormous political effort Adolph Hitler devoted to developing the Nazi Party's racist and economic ideologies to justify launching Operation Barbarossa. The astonishingly radical yet influential political propaganda or marketing campaign conducted with Thomas Paine's *Common Sense* during the American Revolutionary War stands in strong contrast to the relatively insipid arguments used by Jefferson Davis to enhance the value of Confederate independence in the minds of its citizens and soldiers, as well as potential European allies. Moreover, what made the War of the First Coalition so revolutionary? It was the highly innovative Enlightenment-inspired propaganda that the young French Republic deployed through paintings, engravings, songs, slogans, pamphlets, and festivals (Dowd, 1951). A similar situation existed during the rapid expansion of the Arab Empire under the first caliphates with its revolutionary use of religious ideology in its war-time propaganda. From a modern ethnic-warfare perspective, military-marketing investments can include the development of political ideologies designed to enhance the value of a historical homeland, promote chauvinistic attitudes of ethnic superiority, or construct the perception of an existential cultural threat (Hanlon, 2009).

A marketing investment could also involve a government's effort to censor the media, especially to undermine the arguments of anti-war proponents, as well as the propaganda of enemy states. Such an investment can also involve "framing" media discourse of the benefits and costs of fighting a war to steer the debate towards the government's views, as the Bush Administration demonstrated so masterfully before the U.S. invasion of Iraq (Almahrooqi, 2014). Finally, a marketing investment could also involve arguments designed

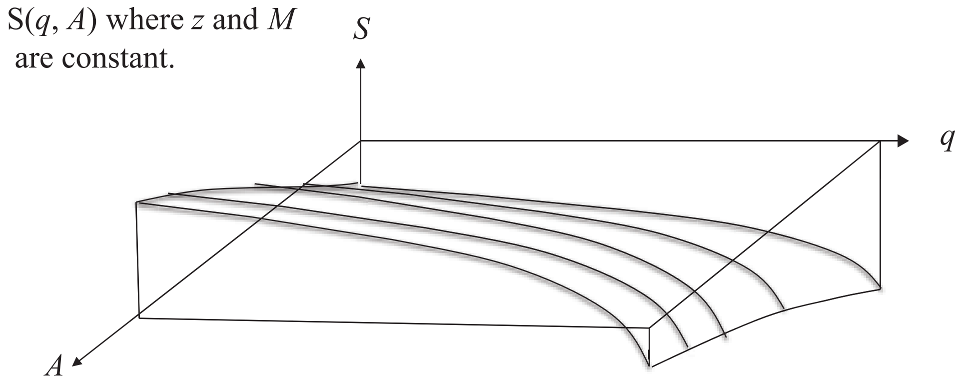

Figure 8: Average Attack-Benefit, *S*, as a funcion of destruct launch rate, *q*, and and advertising investment, *A*.

by diplomats for peace negotiators to bargain for the greatest possible concessions from the enemy state. As argued by Smith and Stam (2004), the success of such bargaining directly depends on the convergence of adversaries' views regarding the evolving cost-benefit relationships associated with the conflict. Such bargaining arguments might involve threats of new dimensions of conventional warfare or an even collective punishment of civilians should the conditions be rejected.[9] Examples include the Allied threat of occupation should the German delegation not sign the Treaty of Versailles or the U.S. threat against Japan to drop even more A-bombs should an unconditional surrender not be forthcoming. It could also involve highly motivating yet low-cost concessions, like Truman's decision to let Hirohito remain on the Imperial throne or Grant's generosity in paroling the soldiers of the Army of Northern Virginia at Appomattox Court House instead of marching them en masse into diseased POW camps. As shown in Fig. 7, the marketing investment can push up the average attack-benefit function, $S(z)$, but like the supply-side investments, it is subject to diminishing marginal returns as the $S(M)$ function flattens out. Khomeini discovered such a basic economic principle, much to his intense chagrin, when all his ideological rhetoric and threatening persuasion could not compel Iran to struggle sufficiently enough to defeat Saddam Hussein's forces. The diminishing returns of Nazi Germany's wartime propaganda investment during the final stages of World War II was manifest by the need to hang soldiers and civilians who revealed defeatist attitudes from lamp posts and trees in ever increasing numbers.

A marketing investment by itself is of little value unless accompanied by an investment in distributing it to relevant audiences. This function is played by the advertising investment. It seeks to increase or shift to the right the average attack-benefit function, as represented in Fig. 8. As with the marketing investment, however, it eventually reaches a point of diminishing marginal returns. Plenty of historical examples point to the significance of this investment, however much it gets taken for granted in many military histories. What would have amounted to Martin Luther's war-motivating analyses and critiques, not to mention

9 See chapter 1, "The Diplomacy of Violence," in Schelling (1966, 1–34).

the searing anti-Catholic propaganda engravings, had so many printing businesses not been available to ensure their cost-effective distribution during the Protestant Reformation (Cole, 1984)? Likewise, what impact would the highly motivating propaganda visual art of the Allies in general and the Italians in particular have during World War I, if the lithograph innovation of Senefelder was not available to reproduce them so inexpensively as posters and postcards (Row, 2002)? After all, World War I represented the revolutionary application of mass production to both the supply side and demand side of warfare. From this perspective, the Prophet Mohammed's (PBUH) title of the "Messenger of God" may have also reflected a down-to-earth reason. An integral advertising or information-distribution investment for his military campaign to transform the warring tribes of Arabia into a harmonious Islamic society was the network of preachers he organized to memorize and recite his sermons to far-flung audiences of both the faithful and the skeptical. Thomas Paine's genius in writing *Common Sense* lay in using a style that made it easy to read out loud in a captivating manner in the taverns and public houses throughout the thirteen American colonies in 1776 (Sigelman, Martindale, and McKenzie, 1996/1997). Furthermore, despite all the efforts Hitler took to mesmerize, if not hypnotize, his live audiences with his body language when giving speeches, he also took great pains to ensure that his rhetoric conveyed well on the radio. That technology reduced substantially the advertising investment of the Nazi Party to generate its vast domestic political support, as well as discourage adversaries (Graves, 1940). Yet when making tactical investments in "psychological warfare" to suppress the morale of Allied troops, the Nazis also relied on "Guttenberg-style" printed leaflets. The enforcement of media censorship, from this perspective, represents a defensive advertising investment, where the objective is to suppress the distribution of enemy propaganda.

In this era of the Internet-fueled global mass media, many might assume the advertising investment is a trivial factor for the strategic management of military campaigns. After all, both the pro-and anti-regime forces of the Syrian Civil War rely heavily on YouTube to broadcast virtually for free their propaganda videos (Baker, 2013). Nevertheless, the competition remains fierce for the attention of easily distracted audiences, especially with the declining cognitive processing capability associated with media multitasking (Ophir, Nass, and Wagner, 2009). This may explain the brutal atrocities displayed in the vengeful propaganda videos of the Syrian Civil War. Many armed non-state actors have traditionally engaged in sensational acts of terrorism to dramatically reduce their advertising investment costs, as demonstrated by Black September during the 1972 Munich Olympic Games, and more recently by Al Shabab in the Westgate Shopping Mall of Nairobi. Wilkinson (1997) defends the idea that such actions represent a symbiotic relationship with the media.

11. Conclusion

This article suggests that a common analytical foundation exists for strategic thinking in both commercial enterprise and military conflict. The same benefit-cost-investment (or ends-means-ways) reasoning embodied in the ROI objective function applies to both, however much the details of the average attack-cost function and the average attack-benefit function vary from their business counterparts. Given the vast academic fortifications that divide the disciplines of business administration and security studies, this has substantial intellectual implications. Nevertheless, while the modeling of a commercial ROI objective function is difficult, the economic relationships associated with the pursuit of military profitability are more complex, as the need to integrate both material and human costs in warfare suggests. The average attack-cost function and the average attack-benefit function of the ROI objective function represent what a military system is capable of achieving for a wide range of investment resources and technical specifications. From the perspective of strategic planning, constructing these functions invariably involves quite subjective estimates. Such a limitation, however, hardly eliminates the ROI objective function's utility for strategic thinking, Just as the vast majority of engineers apply with great success Newton's Laws of Motion and Maxwell's Equations implicitly on a purely qualitative level, the ROI objective function has immense utility for practitioners. It provides fundamental analytical relationships that reveals how a host a seemingly unrelated variables on both the supply side and demand side of warfare are actually deeply coupled within a single algebraic relationship. Without such theory, these insights must be learned haphazardly and intuitively on the job with great frustration and cost. On a broader scale, both political and military leaders have committed devastating strategic, diplomatic, acquisitional, operational, and tactical military errors due to ignorance of even a qualitative understanding of how the relationships contained in the ROI objective function interact. To facilitate the learning of such theory, students can work on determining the optimum independent variable with calculus when meaningful algebraic models of the average attack cost and average attack benefit functions are provided. Nevertheless, this article is not only an appeal for the utility of formal analytical reasoning in strategic military thought from both war-fighting and peace-maintaining perspectives. It also reveals the need for historical study. Even a study of ancient history, such as Thucydides' *History of the Peloponnesian War*, can inculcate rigorous strategic military thinking by articulating the fundamental dilemmas of allocating resources and specifying performance standards in preparing for, preventing, waging, and concluding wars successfully. Such history needs to be disciplined by formal economic reasoning, however, so that the "lessons learned" can be effectively translated into relevant insights when grappling with today's challenges. Brauer and van Tuyll (2008) have already demonstrated such a synthesis by analyzing military strategies in history with six general economic principles. The purpose of this article is to show how it can be accomplished on a broader scale with a single equation.

Acknowledgements

I wish to express my appreciation to Dr. George Tanner of the U.S. Department of Homeland Security and Dr. Jose Colon of the Joint Improvised Explosive Device Defeat Organization (JIEDDO) for their research support. I also need to thank Dr. Douglas Samuelson and the Washington Institute of Operations Research and Management Science (WINFORMS), as well as Robert Kocher, Michael Smith, and Loren Ambs of Ideal Innovations, Inc. for their critical responses and encouragement. Let me also express my appreciation for the motivating feedback I received from Dr. Thomas Blau, my former colleague at NDU's College of International Security Affairs, and my master's thesis students there: Major General Syed Shafqat Asghar (Pakistan Army), Wing Commander Nagarajan Narayanan (Indian Air Force), and Lt. Col. Osama Alzoubi (Joint Special Operations Command, Jordan). Finally, I wish to thank Lorraine Charles, Aya Abdel Yassein and Abdel Razek Yassein for their editorial assistance in preparing this article for publication.

References

Abdelfattah, Yasmine M., Aamer S Abu-Qarn, J. Paul Dunne, and Shadwa Zaher. 2013. "The Demand for Military Spending in Egypt." *Defense and Peace Economics* 25: 231–245.

Almahrooqi, Khaled. 2014. "News TV Coverage during Conflicts: A Study of Media Information Control and its Influence on Security." M.A. Thesis. Institute for International and Civil Security, Khalifa University.

Baker, Aryn. 2013. "The YouTube War." *Time* 181(20): 38–43.

Bar-Josph, Uri. 2006. "Last Chance to Avoid War: Sadat's Peace Initiative of February 1973 and its Failure." *Journal of Contemporary History* 41: 545-–556.

Baumol, William J. 2010. "Preface." In *The Invention of Enterprise: Entrepreneurship from Ancient Mesopotamia to Modern Times*, edited by D. Landes, J. Mokyr and W. Baumol. Princeton: Princeton University Press, ix-xiv.

Benmelech, Efraim and Claude Berrebi. 2007. "Human Capital and the Productivity of Suicide Bombers." *Journal of Economic Perspectives* 21: 223–238.

Berrebi, Claude. 2009. "The Economics of Terrorism and Counterterrorism: What Matters and Is Rational–Choice Theory Helpful?" In *Social Science for Counterterrorism: Putting the Pieces Together*, edited by P. Davis and K. Cragin. Santa Monica: RAND, 151–208.

Biddle, Stephen. 2004. *Military Power: Explaining Victory and Defeat in Modern Battle*. Princeton: Princeton University Press.

Bracevich, A. J. 1986. *The Pentomic Era: The US Army Between Korea and Vietnam*. Washington, DC: National Defense University Press.

Brauer, Jurgen and Hubert van Tuyll. 2008. *Castles, Battles, and Bombs: How Economics Explains Military History*. Chicago: University of Chicago Press.

Brodie, Bernard. 1949. "Strategy as a Science." *World Politics* 1: 467–488, reprinted in 2008. *Strategic Studies: A Reader*, edited by Thomas Mahnken and Joseph Maiolo. Milton Park: Routledge, 8–21.

Clausewitz, Carl von. 1976. *On War*, edited and translated by Michael Howard and Peter Paret. Princeton: Princeton University Press.

Cole, Richard G. 1984. "Reformation Printers: Unsung Heroes." *The Sixteenth Century Journal* 15: 327-339.

Collier, Paul and Anke Hoeffler. 2004. "Greed and Grievance in Civil Wars." *Oxford Economic Papers* 56: 563–595.

Cuddy, Edward. 2003. "Vietnam: Mr. Johnson's War. Or Mr. Eisenhower's?" *The Review of Politics* 65: 351–374.

Dowd, David. 1951. "Art as National Propaganda in the French Revolution." *The Public Opinion Quarterly* 15: 532–546.

Elkus, Adam. 2012. "A Critical Perspective on Operational Art and Design Theory." *Small Wars Journal.* April 30.

Eltis, David. 1995. *The Military Revolution of Sixteenth-Century Europe*. New York: Barnes and Nobel Books.

Ezell, Edward. 1984. *The Great Rifle Controversy: Search for the Ultimate Infantry Weapon from World War II Through Vietnam and Beyond*. Mechanicsburg: Stackpole Books.

Finsterbusch, Kurt and H. C. Greisman. 1975. “The Unprofitability of Warfare in the Twentieth Century.” *Social Problems* 22: 450–463.

Gabriel, Richard. 2007. *Muhammad: Islam’s First Great General*. Norman: University of Oklahoma Press.

Galula, David. 1964. *Counterinsurgency Warfare: Theory and Practice*. Westport: Praeger Security International.

Glenn, Russell W. and Gina Kingston. 2005. *Urban Battle Command in the 21st Centur*y. Santa Monica: RAND.

Graves, Harold N. 1940. “Propaganda by Short Wave: Berlin Calling America.” *Public Opinion Quarterly* 4: 601–619.

Gray, Colin. 2007. “Irregular Warfare: One Nature, Many Characters,” *Strategic Studies Quarterly* 1.2: 35–57).

Hallahan, William H. 1994. *Misfire: The Story of How America’s Small Arms Have Failed Our Military*. New York City: Scribner.

Hanlon, Querine. 2009. *The Three Images of Ethnic War*. Westport: Praeger Security International.

Hallwood, Paul. 2013. “Quantifying Greed and Grievance in the American War of Independence.” *Defense and Peace Economics* 24: 449–463.

Hartley, Keith. 2007. “Defense Economics: Achievements and Challenges,” *Economics of Peace and Security Journal* 2: 45–50.

Haw, James. 2005. “’Every Thing Here Depends Upon Opinion’: Nathanael Green and Public Support in the Southern Campaigns of the American Revolution,” *The South Carolina Historical Magazine* 109: 212-231.

Hayward, Joel. 1998. *Stopped at Stalingrad: The Luftwaffe and Hitler’s Defeat in the East, 1942–1943*. Lawrence: The University Press of Kansas.

Hayward, Philip. 1968. “The Measurement of Combat Effectiveness.” *Operations Research* 16: 314-–323.

Hitch, Charles J. and Roland McKean. 1960. *The Economics of Defense in the Nuclear Age*. Santa Monica: RAND.

Hoag, Malcom W. 1967. “Increasing Returns in Military Production Functions.” In *Issues in Defense Economics*, edited by R. McKean. Cambridge: National Bureau of Economic Research, 3–23.

Johnson, David E. 2000. “From Frontier Constabulary to Modern Army: The U.S. Army between the World Wars.” In *The Challenge of Change: Military Institutions and New Realities, 1918-1941*, edited by H. Winton and D. Mets. Lincoln: University of Nebraska Press, 162–219.

Jowett, Garth S. and Victoria O’Donnell. 2012. *Propaganda & Persuasion*, Fifth Edition. Los Angeles: SAGE Publications, Inc.

Longacre, Edward G. 2011. *War in the Ruins: The American Army’s Final Battle Against Nazi Germany*. Yardley: Westholme Publishing.

Lischer, Sarah K. 2007. “Military Intervention and the Humanitarian ‘Force Multiplier’.” *Global Governance* 13: 99–118.

Luttwak, Edward N. 2001. *Strategy: The Logic of War and Peace*. Cambridge: The Belknap Press of Harvard University Press.

Mahnken, Thomas G. and Joseph Maiolo, editors. 2008. *Strategic Studies: A Reader*. Abingdon: Routledge.

Mahnken, Thomas G. 2012. "Strategic Theory." In *Strategy in the Contemporary World: An Introduction to Strategic Studies*, Fourth Edition, edited by J. Baylis, J. Wirtz, C. Gray. Oxford: Oxford University Press, 60–75.

Mao Zedong. 1938. *On Protracted War*. In *Collected Works of Mao Tse-tung*, Vol. II Beijing: Foreign Languages Press.

Mauskopf, Seymour H. 2005. "Chemistry in the Arsenal: State Regulation and Scientific Methodology of Gunpowder in Eighteenth-Century England and France." In *The Heirs of Archimedes: Science and the Art of War through the Age of Enlightenment*, edited by B. D. Steele and T. Dorland. Cambridge: MIT Press, 293-330.

Montague, Dena. 2002. "Stolen Goods: Coltan and Conflict in the Democratic Republic of Congo." *SAIS Review* 22: 103–118.

Munoz, Arturo. 2012. *U.S. Military Information Operations in Afghanistan: Effectiveness of Psychological Operations in Afghanistan 2001-2010*. Santa Monica: RAND.

Murphy, Dennis and James F. White. 2007. "Propaganda: Can a Word Decide a War?" *Parameters* 37: 15–27.

Naveh, Shimon. 1997. *In Pursuit of Military Excellence: The Evolution of Operational Theory*. Milton Park: Frank Crass Publishers.

Neumann, Peter R. and M. L. R. Smith (2005) "Strategic Terrorism: The Framework and its Fallacies." *Journal of Strategic Studies* 28: 571–595.

Ophir, Eyal, Clifford Nass, Anthony Wagner. 2009. "Cognitive control in media multitaskers." *Proceeding of the National Academy of Sciences* 106: 15583-15587.

O'Shaughnessy, Jackson Nicholas. 2004. *Politics and Propaganda: Weapons of Mass Seduction*. Ann Arbor: The University of Michigan Press.

Osinga, F. 2007. *Science, Strategy and War: The Strategic Theory of John Boyd*. Abingdon, UK: Routledge.

Papacino D'Antoni, Alessandro Vittorio. 1789. *A Treatise on Gunpowder, A Treatise on Firearms, and a Treatise on the Service of Artillery in Times of War*. Translated by Captain Thomson. Whitehall: T and J. Edgerton. Republished by Kessinger Publishing Reprints.

Peck, Merton J. and Frederic M. Scherer. 1962. *The Weapons Acquisition Process: An Economic Analysis*. Boston: Division of Research, Graduate School of Business Administration, Harvard University.

Plehn, Michael T. 2005. "The Sharpest Sword: Compellence, Clausewitz, and Counterinsurgency," unpublished academic research paper. Maxwell Air Force Base: Air University.

Ramey, Timothy L. and Edward G. Keating. 2009. *United States Air Force Aircraft Fleet Retention Rates: A Historical Analysis.* Santa Monica: RAND.

Redlich, Fritz. 1959. "Contributions in the Thirty Years' War." *The Economic History of Review* 12: 247–254.

Roland, Alex. 1978. *Undersea Warfare in the Age of Sail.* Bloomington: Indiana University Press.

Rotte, Ralph and Christoph A. Schmidt. 2003. "On the Production of Victory: Empirical Determinants of Battlefield Success in Modern War." *Defense and Peace Economics* 4: 175–192

Row, Thomas. 2002. "Mobilizing the Nation: Italian Propaganda in the Great War." *The Journal of Decorative and Propaganda Arts* 24: 140–169.

Schelling, Thomas. 1966. *Arms and Influence*. New Haven: Yale University Press.

Scherer, Frederic M. 1964. *The Weapons Acquisition Process: Economic Incentives*. Boston: Division of Research, Graduate School of Business Administration.

Schultz, Richard H. 1979. "Coercive Force and Military Strategy: Deterrence Logic and Counterinsurgency." *Western Political Quarterly* 34: 444–466.

Sigelman, Lee, Colin Martindale, and Dean McKenzie. 1996/1997. "The Common Style of 'Common Sense'." *Computers and the Humanities* 30: 373–379.

Smith, Alastair and Allen C. Stam. 2004. "Bargaining and the Nature of War." *Journal of Conflict Resolution*. 48: 783–813.

Smith, Mark A. 1997. "Sherman's Unexpected Companions: Marching Through Georgia With Jomini and Clausewitz," *The Georgia Historical Quarterly* 81: 1–24.

Smith, Ron. 2009. *Military Economics: The Interaction of Power and Money*. New York: Palgrave Macmillan.

Spinetta, Lawrence. 2008. "Strategy and Cost: A Gap in Our Military Decision-Making Process." *Air and Space Power Journal* 22(3): 89-96.

Steele, Brett D. 2013. "Unifying the Supply Side and Demand Side of Business Strategy with an ROI Objective Function." *The International Journal of Engineering Management and Economics* 4: 18–53.

Steele, Brett D. 2005. "Military 'Progress' and Newtonian Science in the Age of Enlightenment." In *The Heirs of Archimedes: Science and the Art of War through the Age of Enlightenment,* edited by B. D. Steele and T. Dorland. Cambridge: MIT Press. 293–330.

Steele, Brett D. 2005b. *Military Reengineering between the World Wars*. Santa Monica: RAND.

Steele, Brett D. 1995. "An Economic Theory of Technological Products." *Technological Forecasting and Social Change* 49: 221–242.

Sullivan, Patricia L. 2007. "War Aims and War Outcomes: Why Powerful States Lose Limited Wars." *The Journal of Conflict Resolution* 51: 496-524.

Taylor, Philip M. 2003. *Munitions of the Mind*. Third Edition. Manchester: Manchester University Press.

Warden, John A. III. 1995. "Air Theory for the 21st Century." In *Battlefield of the Future: 21st Century Warfare Issues,* edited by B. Schneider and L. Grinter. Maxwell Air Force Base: Air University Press, 103–125.

White, Charles. 1988. *The Enlightened Soldier: Scharnhorst and the Militarische Gesellschaft in Berlin, 1801-1805*. New York: Praeger.

Wilkinson, Paul. 1997. "The Media and Terrorism: A Reassessment." *Terrorism and Political Violence* 9: 51–64.

Yergin, Daniel. 1991. *The Prize: The Epic Quest for Oil, Money, and Power*. New York: Simon and Schuster.

Zweibelson, Ben. 2012. "Seven Design Theory Considerations: An Approach to Ill-Structured Problems." *Military Review,* November-December, 80–89.