



# The Art of Cost

## Sun Tzu's Strategic Insights in Cost Estimating

### Introduction

Master Sun's Military Methods, more commonly known as "The Art of War" [1], is one the greatest enduring works of military strategy. Written during the contentious Warring States period of China's history, the author(s) invoke the name of Sun Wu (granting him the title Tzu, or "Master") to assert that the deft use of the military is as important, or even more important, than other areas of governance. The lasting popularity of The Art of War<sup>1</sup> can be attributed both to its own merit as a treatise on strategy and to the ease with which its advice and proscriptions can be applied to a wide variety of situations. This has led to the work being commonly quoted, and misquoted. At a cursory glance The Art of War comes across as a collection of pithy sayings; for example "If you know the enemy and know yourself, you need not fear the result of a hundred battles" (The Art of War 3:18). While these statements resonate with most readers and listeners; isolated from the larger narrative they are challenging to put into practice.

The Art of War is a fascinating work giving a glimpse of the cultural and philosophical thought of ancient China, and it is the strategic insights contained therein that this paper wishes to explore. Strategy is the process that is employed to determine how political purpose is translated into action. Clausewitz in his grand work "On War" argued that war serves a political purpose. This is as true for war as it is for cost estimation; which at its most fundamental level attempts to determine the level of resources needed to achieve a political end.

In each section of this paper I will introduce and examine the various teachings and proscriptions found in the Art of War and then discuss cost estimating parallels. These topics include the 5 factors that govern war, the 5 essentials of victory, the 4 methods of engaging in war, and the 5 types of spies. Throughout the text you will encounter certain key words and concepts such as: credibility and how it is linked to victory, the Moral Law and the relationship between the ruler and the general, and biased/unbiased as it relates to the process of estimation.

### The Five Factors

*"The art of war, then, is governed by five constant factors, to be taken into account in one's deliberations, when seeking to determine the conditions obtaining in the field"*

The Art of War 1:3

The five factors (illustrated in Figure 1) that Sun Tzu asserts that the general must consider are: The Moral Law, Heaven, Earth, The Commander, and Method and Discipline. All the variables of war can be categorized or bucketed into one of the five factors. In an examination of these factors, the general can forecast victory or defeat.

### The Moral Law

*"The moral law causes the people to be in accord with their ruler, so that they will follow him regardless of their lives, undismayed by any danger."*

The Art of War 1:5-6

The first of the Five Factors, the Moral Law, can perhaps be most succinctly summed up as "harmony". Harmony between the ruler and the people is critical to the efficient and orderly function of the state. It is the moral obligation of the people to follow the direction of their ruler, and reciprocally, it is the obligation of the ruler to act in a moral way. A ruler bereft of morality loses

<sup>1</sup> While Sun Wu did not write The Art of War, nor is that the literal translation of the work's title, I

will from here on use the name Sun Tzu and The Art of War due to common usage.



Figure 1: The Five Factors governing war.

the loyalty of their followers, and a ruler whose people do not follow them is not truly a ruler at all.

The Moral Law applies at every level of authority from the King to the head of an individual household. The Art of War focuses on two primary actors in leadership roles for whom the Moral Law applies. They are the political ruler and the general. The Art of War makes the significant claim that the general must wield the power of the military, not the ruler. The Art of War was written in a time when “martial virtue” and “glory in combat” were a significant social aspect to war. Sun Tzu argues against this, advocating instead that leadership over the military should be invested into an expert in martial matters and that the ruler should value the general’s skill in military matters above all.

A parallel can be drawn to cost estimation; the ruler who embodies and abides by the Moral Law is like the Program Manager (PM) and the general is the Cost Estimator<sup>2</sup>. The PM is responsible for all aspects of their program, from the development phase through demolition. It is the PM that is responsible for establishing the technical, schedule and other requirements that feed into the cost estimate, similar to how the ruler establishes the political goals and objectives for military

action. It is the cost estimator, using his learning and expertise, who independently translates those requirements into a cost estimate.

One of the greatest challenges faced in cost estimation is this requirement for independence, and most modern programs have instituted checks and balances to support the independence of the cost estimator. These checks and balances can come in the form of a CAPE ICE, GAO audits, or independent cost review panels. The PM, however, remains strongly incentivized to influence the cost estimate. This can come in the form of intentionally underestimating the cost to get initial program funding knowing that once started a program will rarely get canceled to over estimating the cost of a program to amass a safety net of management reserve funding. A PM has control over significant cost drivers, such as schedule and technical requirements, and can choose to require the estimate not to reflect realistic risk margins on those items. For cost estimators that are embedded inside the program office there is little that can be done to remove such negative influence as the program office estimate is under the control and approval of the program manager. To push back or refuse Program Manager direction would be a violation of the Moral Law. Even for estimators that are removed from under the direct control of the PMs this can still be a challenge, as much of the data that they use to construct their estimates may be influenced by the program.

Sun Tzu considers these issues to be of paramount importance, hence the Moral Law being the first of the Five Factors governing war. Sun Tzu recognizes that war is a political tool to be used to defend and strengthen the state, but the practical application of war is sufficiently different from other political functions that the general should not be directed by the ruler. The ruler should establish the overarching goals for the general, the general should be left to determine how best to achieve those ends. Similarly the program manager establishes the requirements of a

<sup>2</sup> Program Manager in this context is the individual or group that has direct authority over

programmatic decisions and the term is not being used to denote a Government Program Manager

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program, it is the cost estimator who then takes those requirements and determines what it will cost to achieve that goal. True independence cannot be achieved, but when both the program manager and the cost estimator are in harmony with the Moral Law a superior cost estimate can be created.

Heaven

*“Heaven signifies night and day, cold and heat, times and seasons.”*

The Art of War 1:7

The second of the Five Factors, Heaven, embodies the aspects of war that the general cannot control. No strategist or ruler, however gifted, can command spring to follow summer, the rivers to flood or recede, or the winds to blow. While not controllable, it is not difficult to predict when the Sun will rise and set, and whether or not the Moon will be full or new. Sun Tzu’s second of the Five Factors instructs the clever combatant that they must be mindful of those things that are beyond control; to plan for them, to not be taken unawares, and to use them to advantage.

In cost estimation the skilled estimator has many tools at their disposal over which they exert total control. In response to the sounding of requirements, the cost estimator marshals these tools; regression analyses, historical data, analogies, and spreadsheets. Despite all the rigorous mathematical tools that the estimator can bring to bear, there will always be an element of uncertainty in estimation. It is the uncertainty that surrounds both the known and the unknown that has the greatest effect on an estimate.

Despite building a professional workforce of independent cost estimators the Department of Defense continues to struggle with cost overruns on acquisition contracts. A recent 2014 study published by the Government Accountability Office (GAO) [2] found that of the 78 programs examined, 53% of Research and Development

contracts and 46% of Procurement contracts were over budget. After many decades of experience and learning are we to believe that the field of cost estimation has continued to make the same mistakes year after year? I do not believe this to be the case.

The German military strategist Helmuth von Moltke famously stated “no battle plan survives contact with the enemy” [3], and this is very true for acquisition strategies as well. Risks and uncertainties abound at every stage of the acquisition life cycle and a misstep will result in cost growth or diminishment in delivered capability. It is impossible for a cost estimate to capture and control for all of the risks and uncertainties surrounding a program, but the attempt must be made.

Program decision makers have a strong incentive to accept cost estimates that under-predict the cost of a new capability. It is the estimator’s job to quantify the unquantifiable, to account for the known and unknown, and this is accomplished by incorporating uncertainty and risk in the cost estimate. Because cost estimates determine the budget assigned to acquire new capabilities these drives are in opposition.

Uncertainty, Heaven, the uncontrolled, is a factor in all cost estimating. A cost estimator that does not understand risk and uncertainty is one who will fail. However, as we will see later in the discussion on the Five Essentials of Victory, cost overruns are not a sign of failure of the cost estimate.

Earth

*“Earth comprises distances, great and small; danger and security; open ground and narrow passes; the chances of life and death.”*

The Art of War 1:8

With the third of the Five Factors, Sun Tzu emphasizes the importance of understanding the impact that the Earth, or terrain, can have on the outcome of battle. Has the enemy withdrawn into

mountain passes waiting to ambush the approaching army? From which direction should your army attack the enemy's encampment? In each of these cases the terrain would afford one side of the engagement significant tactical advantages.

In the time of Sun Tzu, war was fought almost exclusively on the surface of the Earth and so considerations of distance and terrain were of paramount importance. In chapter ten of *The Art of War* Sun Tzu identifies 6 different types of terrain and gives general advice on what you should do with each of them. Sun Tzu identifies these terrains by their strategic nature rather than by their geographical nature; accessible ground, entangling ground, temporizing ground, etc. The clever combatant therefore must be cognizant of the strategic considerations that each type of terrain presents.

In the very literal sense, terrain can be a factor in cost estimating as well. For example, a satellite system will have a very different life cycle cost estimate profile from a land-based vehicle. This is due to satellite systems not operating in an environment conducive to maintenance, therefore requiring more extensive development to maximize operational life expectancy. Another good example of terrain effects on cost estimating is locality costs; labor costs can vary wildly depending on the location.

The concept of terrain does not need to be limited to the literal though. A different interpretation of the third factor is that terrain represents the medium in which cost estimating occurs. The gifted cost estimator is well educated in using software applications to build cost estimates. There are a great many different software applications that are employed to develop cost estimates, such as Microsoft Excel or the ACEIT suite of tools, and they each have their own foibles. A gifted cost estimator must understand these tools in order to use them to their potential; must understand how to use the built in functions, be knowledgeable of the ins and outs of the analysis tools, and adept at manipulating and managing the interface. Just as you cannot master the Art of War without an

understanding of terrain and how it impacts strategic and tactical thinking, you cannot master the art of cost estimating without developing a familiarity with the software applications that serve as the terrain in which cost estimates are developed.

#### The Commander

*"The Commander stands for the virtues of wisdom, sincerity, benevolence, courage and strictness."*

The Art of War 1:9

The fourth of the Five Factors that Sun Tzu believes that can be used to determine the outcome of war is the moral quality of the general. One of the main goals of the Art of War, as stated earlier, is that the general must lead and direct the military and not the political ruler of the state. This is because the capable general will have trained extensively for this role; he will be more educated in military matters than the ruler who has been more concerned with other political tasks. Education being instrumental to proper governance was one of the core tenets to Confucianism. It should come as no surprise then that the five virtues for the general are very similar to the Five Constant Virtues of Confucianism (Benevolence, Righteousness, Propriety, Wisdom, and Fidelity). By adopting (with minor adaptations) the moral dictates of Confucianism, Sun Tzu framed the general's primacy in military matters as the logical extension of Confucian teachings.

No such universally recognized and respected moral code exists in modern day culture which we can leverage in a similar way. It is safe to say, however, that most of the Confucian virtues are still held up as desirable characteristics. Benevolent team members and leaders place importance on being kind, and will act in a manner that is more likely to benefit the team and the mission rather than themselves. A cost estimator possessed of sincerity and righteousness builds a

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reputation for integrity and honesty which fosters credibility in their estimates. A strict estimator is one who follows best practices and processes at all times, not just when it is convenient for them. And a wise estimator knows how to harmoniously balance all of the demands of estimating to achieve a coherent whole.

The value that Sun Tzu placed on education and why this meant that the general was best suited to lead the country in military matters is one that holds true to this day. The proliferation of centers of higher education, universities, academies and colleges, provide ample evidence of the value that our society places in higher education. Certification programs exist to educate cost estimators to ensure a baseline level of proficiency and familiarity with cost estimating techniques and processes. While the average person is capable of estimating what pizza delivery is going to cost them or the price of a gallon of milk; it is altogether a different thing to estimate the cost of constructing a building or developing a new fighter jet. These tasks are best left to cost estimators, who have been trained and educated in the necessary techniques.

#### Method and Discipline

*“By method and discipline are to be understood the marshaling of the army in its proper subdivisions, the graduations of rank among the officers, the maintenance of roads by which supplies may reach the army, and the control of military expenditure.”*

The Art of War 1:10

Perhaps the most overlooked consideration of military matters by the arm-chair general is the fifth and final of the Five Factors, logistics. It is as true today as it was in the time of Sun Tzu that logistics was a critically important consideration for the general. Logistics is the discipline of ensuring adequate supplies for your troops, properly maintained roads or means of transport, a structured chain of command and lines of

communications, etc. In short, logistics is the means by which the state can execute strategy and tactics.

In cost estimation logistical concerns are those foundational elements which are critical to the development of a cost estimate. These include the construction of a Point of Contacts list, a data database from which CERs can be extracted, and organization charts that identify roles and responsibilities for all team members to name a few. While these elements are not cost drivers in an estimate, they can be highly influential. Failures in properly maintaining cost estimate logistics can only increase the difficulty in developing credible cost estimates. It is imperative that the cost estimator have an understanding of the logistical systems upon which their cost estimate depends.

#### The Five Essentials of Victory

In the time of Sun Tzu, victory in war was easy to identify and define; when two armies clash, the losing army surrenders to the victor. Sun Tzu does not invest any time in discussing how to turn a seemingly lost tactical battle into a strategic victory. To Sun Tzu, the victor in war is readily apparent after the conflict is complete. He proposes 5 strategic essentials to victory in war. These are:

- He will win who knows when to fight and when not to fight
- He will win who knows how to handle both superior and inferior forces
- He will win whose army is animated by the same spirit throughout all its ranks
- He will win who, prepares himself, waits to take the enemy unprepared.
- He will win who has military capacity and is not interfered with by the sovereign.



These Five Essentials, in combination with the Five Factors governing the conditions in war, are critical in determining and predicting the outcome of any conflict. How do these strategic essentials translate into the cost estimation process? Before we can discuss how to achieve victory in cost estimation, we need to identify what victory means in the context of cost estimation.

Many people's first instinct in evaluating the success of a cost estimate is answering the question, "is the cost estimate right?" This is the greatest irony of cost estimating; people have a great deal of faith in mathematics as it is perhaps the invention/discovery of humanity that comes closest to being a universal truth, yet cost estimates are mathematical models whose accuracy cannot be determined. For obvious chronological reasons the ability of an estimate to predict the eventual cost of a program cannot be determined and after a program has concluded it is very challenging to determine whether the cost estimate predicted the cost or dictated the cost (i.e. the program spent all of its available money regardless of need). The failure of accuracy as a metric for measuring cost estimates is due to a misunderstanding of the nature and purpose of cost estimates. Cost estimates are just that, estimates, and while they are more than likely wrong they can still be useful. The Government Accountability Office (GAO) describes high-quality estimates with the term "credible" and provides a 12 step process by which credible estimates can be generated [4]. We will therefore use credibility as the metric for cost estimating victory.

According to the GAO Cost Estimating and Assessment Guide credible estimates share the following characteristics: clear identification of the item being estimated, early involvement from all stakeholders, employ valid data, standardized estimating structure, considers program risks, recognition of inflation, comprehensive of all related program costs, independently reviewed, and revised at major program changes. On the surface, some of these characteristics are easily relatable to the Five Essentials; the similarity between "He will win who has military capacity

and is not interfered with by the sovereign" and independently reviewed is readily apparent. Let us consider each of the Five Essentials and how they can be leveraged to help build credible victorious cost estimates.

#### When to fight and when not to fight

One of the most important considerations in war is knowing when to strike. Sun Tzu invests a considerable portion of the Art of War discussing the conditions under which the general should engage in open conflict and the how, why and when of fighting. Sun Tzu summarizes his strategic philosophy with the famous saying "If you know the enemy and know yourself, you need not fear the result of a hundred battles" (3: 18). A general who understands the condition of both armies, is familiar with the terrain, is well versed in battle tactics, etc. knows when to fight and not to fight. Little needs to be said to understand why this is a strategic essential to victory.

The analogous cost estimating activity is the process of developing the point estimate. In war, the battle is the culmination of all the planning activities that have preceded it; the strategic maneuverings, the supply and manpower logistics, the recruiting of allies and the gathering of information on the opposing force. The development of the point estimate is also the culmination of all preceding activities; the gathering of historical data, the interviewing of experts, the building of a work breakdown structure, etc. Just as a general might choose not to engage in battle with the enemy if conditions are not favorable, so too should a cost estimator weigh the risks of developing a point estimate based on flawed data (data that hinders credibility rather than supports credibility) or poorly defined requirements. "Thus it is that in war the victorious strategist only seeks battle after the victory has been won, whereas he who is destined to defeat first fights and afterwards looks for victory" (4: 15).

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## How to handle superior and inferior forces

Sun Tzu gives a number of examples on the different tactics you should employ given numerical superiority or inferiority compared to the enemy army. For example, “it is the rule in war, if our forces are ten to the enemy’s one, to surround him” (3: 8). Another good example can be found in “Numerical weakness comes from having to prepare against possible attacks; numerical strength, from compelling our adversary to make these preparations against us” (6: 18). Numerical superiority, however, is not the only way to gauge the superiority. Controlling advantageous terrain, more disciplined troops, or being able to attack the enemies weaknesses are all ways in which a force can be superior.

Just as the able general must know how to best utilize the forces at their command, so too must a cost estimator be able to adjust their cost estimating techniques and methodologies to the data and circumstances specific to their current cost estimate. For example, a cost estimator who is preparing a parametric estimate must examine and understand their data set: are there any outliers, is the data set self-similar, and is there sufficient data to achieve a reasonable regression? If the data set is not appropriate for a parametric analysis (such as the estimate requiring a prediction outside the data set range, or having too few data points) it may be necessary to choose a different cost estimating methodology.

## Animating the army with the same spirit

Sun Tzu understood the human element of war and considered it so important that he listed it as the first of his Five Factors governing war. The Moral Law was the foundational cultural principle behind the relationship both between the ruler and his people and the officer and his men. A general adhering to the Moral Law looked out for the wellbeing of his troops who, in turn, followed the orders of their general regardless of the

personal risk. Sun Tzu provides examples on the proper way to reward troop loyalty and success, such as “When you plunder a countryside, let the spoil be divided amongst your men; when you capture new territory, cut it up into allotments for the benefits of the soldiery.” (7: 20) Sun Tzu also discusses warning signs that the general should be aware of, such as “If there is disturbance in the camp, the general’s authority is weak. If the banners and flags are shifted about, sedition is afoot. If the officers are angry, it means that the men are weary.” (9: 33)

Cost estimators spend a good portion of their time delving into the mathematical world; where there are no interpersonal concerns and the comforts of hard and fast mathematical rules hold sway (this can be deceptive however, one must always remember that cost estimates are estimates and are less accurate than mathematical precision would have us believe). Despite this, human relationships are critical to the success of the cost estimator. For example, developing and maintaining a point of contact list of subject matter experts and keeping in touch with them on a regular basis can help the cost estimator be aware of upcoming issues or events that may impact the cost estimate (such as an upcoming labor rate change on a contract or reveal disagreement on how risky a particular program element is).

For cost team leads it is important to set group priorities and regularly communicate issues to the team. If there is a disturbance in the cost team (i.e. disagreement on the proper team approach and goals), the cost team lead’s authority is weak. As a result the cost estimate developed will not form a harmonious whole; its credibility becomes suspect. The Moral Law states that the cost team should be in accord with the vision of the cost team lead, but this also comes with obligations for the cost team lead. The team lead must seek to understand what motivates their team and should look for every opportunity to reward the good works of the team. This will result in a team that is motivated towards success and more willing to be animated by the driving spirit of the team lead.



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**Be prepared, and take the enemy unprepared**

The concept of the “surprise attack” is well understood; hitting the enemy when they are not ready to counterattack is always strategically advisable. Beyond that, this concept can also apply to striking the enemy before they have a chance to resolve logistical concerns; as we have already discussed, logistics represents the ability of a state to execute strategy. The key element of this piece of advice is the first two words; “be prepared” (the wait to take the enemy unprepared is almost a reiteration of the first essential to victory of knowing when to fight). The general whose army is prepared to fight, withdraw, advance or pillage is one which will be able to perform with better order and discipline.

Similarly, in cost estimating it is important to be prepared. A credible cost estimator will be prepared to defend their estimate. They will know what areas in the estimate are of the greatest interest to reviewers and are prepared to address them. They will have done the prep work to resolve commonly occurring issues. They will tailor their estimate documentation to meet the preferences of the reviewers. Above all, the credible cost estimator needs to know their cost estimate and be able to effectively and confidently communicate the methodologies and assumptions that they have made in creating that cost estimate. There are few quicker ways to lose credibility than to appear like you don’t know what you are talking about.

Additionally, in practice, a cost estimator is often called upon to defend the credibility of an estimate before it is complete to the satisfaction of the estimator. In such cases it is important that the estimator explain the weaknesses in the estimate (such as an incomplete risk evaluation or a poorly documented CER). Having prepared a plan or road map for cost model improvements gives credibility to the estimator and by extension the cost estimate.

**No interference from the sovereign**

Despite the Moral Law and Sun Tzu’s own acknowledgement that “In war, the general receives his commands from the sovereign” (7: 1), the independence of the general in military matters was of extreme importance to Sun Tzu. This essential of victory was one of the primary driving ideas behind the scribing of the Art of War. Sun Tzu discusses three chief ways that the political ruler can interfere with and bring misfortune upon his army. These are: ordering the army to advance or retreat despite circumstances that would make such moves disadvantageous, attempting to govern the army the way they would the rest of their kingdom and using a one size fits all approach to military strategy. Sun Tzu states that these actions, however well intended, result in hobbling the soldiers, causing restlessness among them and shaking their confidence respectively.

Correspondingly, there are many ways in which a program manager can interfere with cost estimating. A program manager can hobble the cost estimator and their estimate by setting unrealistic deadlines for deliverables, being ignorant of the conditions which exist in the estimate (such as data quality or manpower availability). This will result in an estimate that lacks credibility. A program manager can cause restlessness in the cost estimator by tasking them with items more appropriately worked on by budget, contract or execution analysts (while a properly trained cost estimator will be versed in most aspects of acquisition tasks, one should employ the appropriate subject matter expert to a given task). This mistake is often the result of a poor or blurred understanding of the distinctions between those money related positions. A program manager can shake the confidence of the cost estimator by mandating the use of the same cost methodology for every task, through ignorance of the strengths and weaknesses of the differing methodologies. This displays a lack of

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flexibility in program leadership or too strong of a desire to adhere to a rigid template. Adaptation to circumstances is needed to build a credible cost estimate as there is no one size fits all approach.

### The Four Methods of Engaging in War

*“In the practical art of war, the best thing of all is to take the enemy’s country whole and intact; to shatter and destroy it is not so good.”*

The Art of War 3:1

Having looked at what Sun Tzu considers the Five Factors that govern war and the Five Essentials of Victory, next we will examine the broad strategies that can be employed in war and how those strategies can be translated to a cost estimating paradigm.

Sun Tzu noted in war there are four broad strategies employed by generals and he ranked them in order of superiority.

- 1) Attack the enemy’s strategy
- 2) Isolate the enemy from his allies
- 3) Attack the enemy’s army in the field
- 4) Besiege walled cities

There is no good way to draw an analogy between these four methods and cost estimating strategies that does not strain credibility. In this case it is more important to examine and consider why Sun Tzu believed in this order of priorities. Again it helps to examine the historical context in which the Art of War was written.

The concept of “Martial Virtue” has already been brought up in reference to the Moral Law and it informs Sun Tzu’s rankings here. It was seen as necessary by the aristocracy to prove themselves in combat; to gain legitimacy through bravery and glory. Sun Tzu dismisses such concerns as unimportant. Sun Tzu’s statement “supreme excellence consists in breaking the enemy’s resistance without fighting,” (3: 2) would have come as quite the shock to many of his era. This belief recognizes and asserts that there is no glory in combat. War, as a tool of the state, is about

achieving a political end and it is therefore best to minimize the cost (in money, resources and lives) to achieve those ends.

Sun Tzu believed that attacking the enemy’s strategy (“balk the enemy’s plans”) allowed the general to subdue enemy troops without fighting and to capture cities without laying siege. As such, it was the war strategy with the greatest payout to investment ratio. It is this ratio of payout to investment that informs the rankings of strategic superiority. It is intuitively obvious that isolating the enemy from his allies is strategically more optimal than engaging the culmination of his forces (Divide and Conquer is a strategy so old its origin is lost in antiquity), hence it’s placement above attacking the enemy’s army in the field. It is particularly interesting to note that Sun Tzu believed that sieging cities was not a desirable way of conducting war. In this case the ratio of payout to investment was too small or even less than one.

Before jumping back to cost estimating we should further examine another concept that Sun Tzu discusses on engaging in war. In a particularly poetic passage from The Art of War (5:6-11) Sun Tzu attempts to convince the reader that there are but two fundamental methods of attack, the direct and the indirect. It is from this infinite combination and variation of direct and indirect attack that all strategic and tactical maneuvering is derived. He compares this to the five primary colors (red, yellow, blue, white and black) from which it is possible to generate “more hues than can ever be seen” (5: 8); with a similar analogy made to tastes and musical notes. In war, the direct method is employed when directly attacking the enemy, however the indirect methods of attack are needed to ensure and secure victory.

While Sun Tzu would not have been familiar with the example (as it occurred around 300 years after he was born), Hannibal’s victory over the Romans at Lake Trasimene and Cannae during the second Punic war is a wonderful example of mastering the direct, but failing at the indirect [5]. After the Battle of Cannae, Hannibal had done such a good job of killing Romans in open battle that Rome had lost one-fifth of its adult male population. Despite

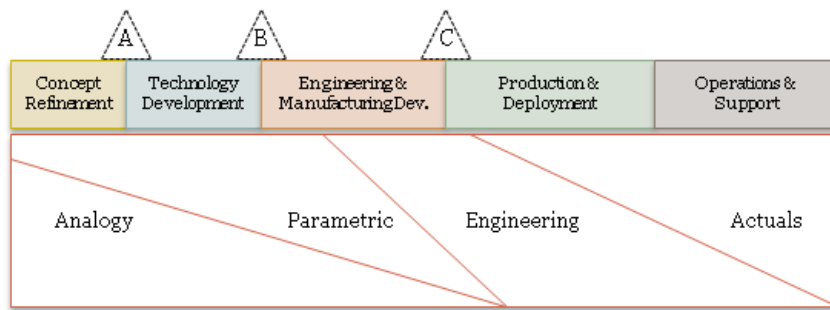


Figure 2: Cost Methodologies and when they are typically used in the acquisition process.

this horrendous loss of life, Hannibal had not been successful in his indirect tactics and had failed to destroy the Roman spirit, and in the end Carthage lost the second Punic war.

With these two concepts in mind: that the best strategies in war are those that achieve victory with the least investment, and that indirect methods of attack are needed to ensure victory, let us now turn back to cost estimating.

In cost estimating, where credibility is victory, there are two fundamental methods of estimation, biased and unbiased. Biased estimating, in this context, is defined as using people as sources; whereas unbiased estimating is defined as using cost data as sources. All cost estimating methodologies and techniques blend these two concepts. The analogy is a methodology that skews biased, i.e. it relies heavily on the input of subject matter experts (SME). The SME provides nearly everything in an analogy, from the analogous system to the adjustment factor. Conversely, parametric modeling methods skew unbiased, drawing data from a wide variety of programs based on characteristics and attributes of those systems with the goal of determining cost estimating relationships buried within the data.

As in war, where direct methods of engaging in conflict do not ensure and secure victory, biased cost estimating methodologies do not ensure and secure credibility. Estimates that rely too heavily on biased methodologies lack credibility due to humanities inherent inability to estimate accurately. Multiple studies have investigated this

phenomenon, finding that an optimistic bias exists even for individuals with extensive knowledge and experience in their field. This optimism bias can be worsened further by strong outside incentives to minimize cost estimates. Programmatic leadership is often motivated to discount, conceal, or otherwise exclude important program

costs and risks to keep costs low and/or on target to gain program approval. Since biased methodologies (such as analogies and engineering build ups) often involve extensive SME input it is difficult to ensure and secure credibility by those means.

The key to the credibility of unbiased methods of estimating is the direct link to historical facts and reality. In a properly constructed cost estimating relationship (CER) every data point can be linked back to a historical program or system. A cost estimate that is built upon verifiable data points is more credible than one that is built upon SME inputs. The accuracy or predictive ability of a cost estimate is not necessarily improved by using unbiased methods, however. Biased cost estimating methods can produce highly accurate cost estimates. For example, the engineering build up methodology is a highly biased form of estimating (the manpower requirements for a task tend to be provided by SMEs in Full time Equivalents (FTEs)) that can be very accurate if the program goes according to plan. However, without any citation of metrics or data sources showing the manpower requirement for the task, it is difficult to claim that the engineering build up estimate has credibility. As stated earlier, credibility is the measure of victory in cost estimating, not accuracy.

Let us now look at the four primary methodologies employed in cost estimating, Analogy, Parametric, Engineering and Actuals, and examine their reliance on biased and unbiased methods and the ratio of payout to investment. A typical cost

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estimate will use a blend of these methodologies to arrive at a Life Cycle Cost Estimate. As a program progresses through the acquisition timeline, methodologies employed in cost estimates also change as more data associated with the program becomes available (as illustrated in Figure 2). For example, an Estimator can't often use the Actuals cost estimating methodology early in a program lifecycle because there are no data to back up the actuals methodology. Conversely, one wouldn't still be using the parametric modeling methodology when deliverable end items have already produced.

**Analogy**

*The cost of **A** will be similar to the cost of **B***

The basic concept behind the Analogy cost estimating methodology is that all new programs will be similar, in terms of capabilities, technologies or characteristics, to a previous program for which historical cost data is available. The analogy uses the historical costs of the known system, often adjusted by a technically based adjustment factor, as the basis of the cost estimate for the new system. Analogies can be established very quickly; however it is a methodology that tends towards heavy bias. Cost estimator and expert opinion subjectivity is involved in the selection of the analogous system and the adjustment factor. While the GAO cost handbook advises the use of adjustment factors that are based upon objective system characteristics, it acknowledges that without rigorous statistical analysis it is impossible to determine whether or not the selected system characteristics are significant cost drivers. Instead, the estimator must rely upon subject matter experts to determine the reasonableness of the analogy.

The heavy dependence on people and opinion renders the analogy a biased cost methodology and thus a method for which it is more difficult to establish and secure credibility in the cost estimate. It is therefore important when using the analogy methodology to emphasize those aspects of it that are unbiased. Consider a fictitious development program, Program Q. Program Q is intended to develop an upgrade to an existing

hardware system by delivering a new capability. The Program Q technical director believes that the new capability they are developing is similar to a previous upgrade developed for the existing hardware system (Program R). A direct analogy of program R to Q would be largely biased: it depends on the opinion of the technical director that the two upgrades were similar. The only unbiased data point in the analogy is the historical cost of Program R. If the cost estimate analogy employed scaling factors based on aspects of technical similarities between Q and R (Q will impact 13 of the hardware subsystems, where R impacted 15) an unbiased element can be added. In this example a straight 13/15 factor would be unbiased. Any method that the cost estimator employs to link the analogy back to technical aspects that the two systems share serves to strengthen the unbiased side of the analogy. While it is impossible to create a cost estimate using the analogy methodology that is fully unbiased, it is necessary to emphasize the unbiased aspects of the analogy to ensure and secure credibility.

**Parametric**

*The cost of **A** can be predicted based on trends*

A cost estimator employing the parametric method builds a statistical relationship between cost and program technical characteristics. Such characteristics can be physical (weight or size), performance (thrust or data transfer rate) or software related (source lines of code or function points). The parametric methodology requires the development of a statistically valid cost estimating relationship using historical data. The heavy reliance on historical data and statistical methods makes the parametric methodology predominantly unbiased. The unbiased mathematical nature of the methodology enables rapid adjustment and modification of the cost estimate to changing technical requirements as there is no need to resurvey subject matter experts when assumptions change or verify that adjustment factors are still accurate. With proper application, the parametric cost estimating



methodology has a high payout to investment ratio and is built using unbiased methods.

It is possible to insert or employ bias in the parametric method through culling and normalizing the data and data sources. Navigating the tricky waters of correlation and causation also requires estimator or subject matter expert judgement. It is possible to construct correlation relationships that, while mathematically sound, would not be deemed credible or reasonable. This is a well understood phenomenon, but as it requires personal judgement it is inherently biased. Many humorous and absurd examples can be found on the Spurious Correlations webpage [6], such as per capita cheese consumption correlating with number of people who die by becoming tangled in their bedsheets.

Another way that bias appears in parametric methods is through the appearance of outliers. For whatever reason, be it the result of a disruptive environmental event or a major technical challenge, some data points can fall far outside an otherwise consistent trend, even in cases where the technical parameters of the outlier program being consistent with the overall dataset. Figure 3 presents data I collected over the course of a year on the gas mileage of my car (a 2000 Saturn LS). Of particular note is the data point in the  $+3\sigma$  to  $+4\sigma$  band; this data point is an outlier (as determined by Grubb's test), however, there is no explanation for why. For some reason my car exceeded 43 mpg for this particular tank of gas (perhaps my wife put a gallon in one day when using the car unbeknownst to me). Would you leave this data point in the dataset if you were constructing an estimate based on this data? Regardless of the answer to this question bias has been introduced into the cost estimate by that choice. Leaving the outlier in the dataset imparts bias; despite the outlier skewing the CER the estimator has decided that the data point is legitimate. Removing the outlier from the dataset imparts bias; the cost estimator has chosen to remove data they feel is illegitimate. This imparted bias can be alleviated by incorporating the outlier data point into the risk analysis in some

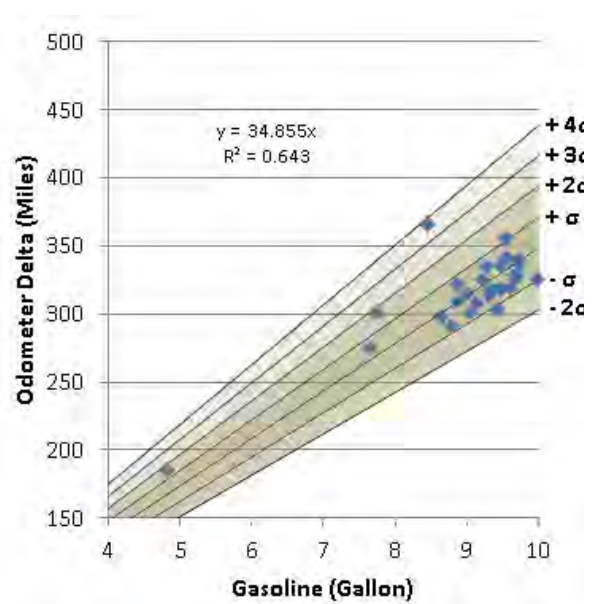


Figure 3: Sample data for parametric analysis of gas mileage of a 2000 Saturn LS

fashion, but this cannot be accomplished in an unbiased fashion either.

#### Engineering Build-Up

*The cost of A is the sum of its component costs*

The engineering build-up cost estimating method involves the construction of a total cost by adding up all lower level work breakdown structure element costs. This bottoms-up style of estimation provides a great deal of programmatic detail and is able to clearly identify what costs are included in the estimate. Because a great deal of information and program knowledge is needed to construct an engineering build-up estimate it is not well suited as a cost methodology early in a program's life cycle (see Figure 2.). It is a cost estimating methodology that heavily relies upon engineering input due to the level of detail and subject matter expert knowledge needed to examine a system at the component level (hence the name). Engineering estimates are typically presented in terms of labor hours and rates, with material, fee and overhead costs added on. These inputs are typically provided by SME engineers working with the cost estimator. As a result much of the input data that gets put into the engineering



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build-up cost estimate is biased in nature. On top of this, engineering build-up cost estimates are very time intensive to generate and are not responsive to what-if drills that fall outside their assumptions.

The engineering build-up cost methodology has a very low payout to investment ratio; it tends to be biased and requires a large amount of time and effort to produce. The engineering build-up method does have its benefits however. It is the natural tendency of programs to gravitate to an engineering build-up methodology as the program enters into the manufacturing and production phases. The planning and building of a product requires a detailed product understanding which goes hand-in-hand with the engineering build-up methodologies requirement of understanding the system to the lowest level. It is therefore the natural desire of program leaders to see the cost estimate align with the structure of the program contracts. This can give program leaders great visibility into the cost drivers and risks. Cost estimating down to the lowest level of the WBS also allows for an easier transfer or comparison of costs between different programs. Using the available standardized WBSs found in the MIL-STD-881C for example, allows the cost estimator to generate component level CERs that can translate across programs.

The engineering build-up methodology does have its risks as well. The high level of detail and preponderance of SME input into the engineering build-up increases the chance that the cost estimate is not truly under the control of the cost estimator. In order to reign in this phenomenon it is critical for the cost estimator to incorporate unbiased cross checks into the estimating process. Only in this way can the cost estimator use the engineering build-up methodology in such a way that it can be considered credible. Another risk that commonly arises is gaps or missing elements in the WBS. When describing a program down to the task level it is very easy to overlook or forget about components, and often the cost estimator is not technically savvy enough to recognize these gaps. To help combat this problem, the cost estimator must solicit additional reviews with

programmatic experts to allow the subject matter experts opportunities to identify and fill in any overlooked WBS elements.

**Actuals***The cost of A will be like previous A costs*

The actuals cost estimating methodology is perhaps the most instinctive method of cost estimating. Humanity has a tendency to expect that what we paid to purchase an item in the past is predictive of what we would need to pay for that item in the future. Because of this tendency, estimation from actuals is considered highly credible. Using cost actuals to extrapolate future costs for the same program is also fast, giving the actuals cost estimating methodology a very high payout to investment ratio. However, cost actuals are not available until late in the program life cycle (see Figure 2) limiting its usefulness.

The actuals cost estimating methodology relies upon unbiased data at the core of the estimate but it is often necessary for estimator judgement, and thus bias, to be exercised. One example of how bias can be introduced is when using earned value management (EVM) data as the basis of the actuals method. Imagine a contract which is almost complete (>70% of the task deliverables are completed) and one wants to use the contract Estimate at Complete (EAC) as the basis of the cost estimate. Should one use the contractor EAC or the government EAC (which are respectively considered the most optimistic and most pessimistic) or something in between? It is advisable to view recent performance in making these judgements, but regardless of the answer bias has been introduced.

The actuals cost estimating methodology dovetails quite well with learning curve theory; both operate on the basic assumption of consistency in the end product. Learning curve factors are often assumed or extrapolated from early test article and low rate production end items. In the first case a significant amount of bias has been introduced to the estimate as the learning curve factor is often a major cost driver. The second method, because of its reliance on unbiased data,

is more credible. Learning curve theory is complicated when breaks in production occur. These breaks can be the result of delayed contract actions (the exercise of a period of performance extension option for example) or labor strikes or material shortages or any number of unexpected events. There exists a method of calculating the retrograde movement back up the learning curve due to any variety of production break, but the method relies upon subjective judgment (bias). For example, it is not possible to determine in an unbiased fashion the proportional impact that process documentation had as compared to tool design and layout to the learning curve.

Other “dangers” to be aware of when using the actuals cost methodology include: delayed invoicing, the difference between recurring and nonrecurring costs, and product configuration stability. For any number of reasons, some cost invoices are not reported or delivered in a timely manner; sometimes even extending years after the costs were incurred. This can result in legitimate product costs being left out of the estimate. Typically late invoices are one off events but this is not necessarily always true. It is important to also differentiate between recurring and nonrecurring costs. When determining the cost of producing a certain number of units it is necessary to ascertain what the recurring costs of production are compared to the nonrecurring. The line between recurring and nonrecurring can be blurred making the delineation a matter of subject matter expert judgement and bias. Finally, product configuration stability is required to legitimize the use of the actuals cost estimating methodology. From a strict standpoint any change, no matter how minor, in the product configuration invalidates the actuals estimate.

#### The Five Types of Spies

*“Knowledge of the enemy’s dispositions can only be obtained from other men.”*

The Art of War 13:6

In the final chapter of The Art of War Sun Tzu reveals the key to “what enables the wise sovereign and the good general to strike and conquer” (13:4), foreknowledge. Foreknowledge of the enemy’s movements and positions, their motivations and their capabilities enables the general to devise his strategies to check the enemy’s strengths and to counter his gambits. It was Sun Tzu’s belief that no amount of deductive or inductive reasoning could be relied upon to discern the intent of the enemy. Measureable and quantifiable elements, such as distances, deliverable units, weight and size are readily available to mathematical determination; but human actions and behavior cannot be so easily calculated. To obtain foreknowledge of the enemy and their dispositions the ruler and the general must employ spies, of which Sun Tzu identifies five types.

1. Local spies
2. Inward spies
3. Converted Spies
4. Doomed Spies
5. Surviving Spies

Local spies can be found amongst the citizens living in the land controlled by the enemy. These are people who have no official capacity, but may know information that is useful to gather. A good example would be a farmer whose land lies near a military garrison that can inform upon the movements of enemy troops. The inward spy is an official within the enemy’s political or military structure. The government ministers and military officers make for excellent sources of information on the enemy’s tactics and dispositions. Converted spies are those individuals that the enemy has placed into your territory that you have identified and then used for your own purposes. This can be accomplished by either convincing them to work for you through payments or improving their station, or by feeding them false information to take back to their masters. The doomed spy is one who is intended to be captured, so that false intelligence can be given to the enemy in a convincing way. A broader definition of the doomed spy is performing actions openly with the intention of deceiving the enemy. The surviving

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spy is any person who was sent out with the intention of gathering intelligence that successfully returns with information.

The use of spies has a fairly intuitive corollary in cost estimation; gathering data. From interviewing SMEs to collecting contractor data reports to mining cost databases for information, there are a myriad of ways that the cost estimator can gather the data needed to develop credible cost estimates. Sun Tzu's focus on information gathering was people. In cost estimating terms, as established earlier, using people as sources imparts an element of bias into the cost estimate. Sun Tzu also recognized the inherent uncertainty and unreliability of using people as sources leading him to state that "spies cannot be usefully employed without a certain intuitive sagacity" (13:15). By this he means that without careful observation and discernment one cannot be sure of the veracity of a spy's claims. Similarly, a credible cost estimate endeavors to verify and justify bias in the cost estimate documentation.

In cost estimating terms a local spy is any person formally associated with the program being estimated that is not in a leadership position. This could be a contractor engineer or an execution analyst or a factory line worker. These people often do not know or see the big picture of the program but are excellent sources of information on specific tasks and elements that make up the overall program. Because these people are at the ground and task level they are well suited to providing highly detailed information at the component level that can be used to help construct engineering build-up and actuals cost estimates. The challenge in establishing local spies for cost estimators is largely a numbers game. The size of the program will often dictate how challenging it is; the larger the program, the more local spies would need to be created in order to gather data on the disparate program elements. Cultivating and determining the credibility of a large number of SMEs is a time consuming task.

The inward spy can be thought of as those individuals in positions of authority that are not directly tied to the program but are nevertheless

familiar with it. The data and information that these people can provide is generally not technical but is more assumption oriented. The basic ground rules and assumptions of a cost estimate can have a very large influence on the point estimate. The inward spy is able to inform the cost estimator of upcoming policy changes and decision points that may have a significant impact on the cost estimate. One example would be the program office receiving notification that the overhead rates for their primary contractor were being renegotiated and as a result would be increasing next year. This is a decision that is being made by people that have no direct relationship with the program office but can have a very significant cost impact to the program. These are the most difficult type of source for the cost estimator to establish and maintain for a number of reasons. First, decision makers that can influence programmatic assumptions are generally outside the social circles inhabited by cost estimators. Second, the number of people that are indirectly tied to a program is often orders of magnitude greater than those that are directly tied to the program; how is the estimator to know who is a good source of potential information? Third, even if the cost estimator has acquired information from an inward spy, the estimator does not have the authority to alter the basic ground rules and assumptions of the cost estimate. According to the Moral Law, those are the purview of the program manager.

The converted spy can be viewed as a duly appointed representative from an outside organization that is directly tied to the program in some way. From the perspective of a government program office this could be the primary contractor representative or point of contact. From a business perspective this could be a vendor representative. The converted spy is supposed to represent the interests of their organization (which typically parallel the interests of the program) but can serve as a valuable source of data for the program. The converted spy can also enable to acquisition of local and inward spies, as they are more familiar with their organization and can identify them for the cost estimator. The converted spy is a good source for data that can

support all types of cost estimating methodologies. The data provided by the converted spy is biased (both in the conventional sense and in the definition used in this paper as data derived from a human decision) and must be subject to extra scrutiny. The converted spy is the easiest spy to establish and maintain; typically the work is done for you. Outside organizations will establish a point of contact as a standard best practice for funneling information in and out of the program.

The doomed spy is not a person in cost estimation (I suspect it would fall victim to some form of ethics violation) but more of an information gathering tactic. As there is no true “enemy” in cost estimating, aside from the constant struggle to assert and establish credibility, there is no “enemy” that the cost estimator is trying to deceive. A minor deviation from the doomed spy can be found in the practice of socializing the data and assumptions of a high profile or contentious cost estimate with the stakeholders. This allows the interested parties to push back or validate the data and assumptions resulting in increased estimate credibility in the eyes of the stakeholders. A more direct application of the doomed spy tactic is attempting to make use of Cunningham’s Law. Cunningham’s Law, named after the creator of the wiki, states “the best way to get the right answer on the internet is not to ask a question, it’s to post the wrong answer”. This can be applied in cost estimation as well. It is possible to create pressure on outside organizations by creating an estimate without their input for programs that will have budgetary implications to those outside organizations. Care must be taken when using this tactic and it should never be the first go to, because it can backfire and it can damage the cost estimator’s credibility.

The surviving spy is not necessarily a person in cost estimation (conventional spying is illegal). In its inhuman guises, the surviving spy could be contractor data reports, proposals, or responses to requests for information. These data sources are the result of the program or contractor requesting particular information and receiving the information in the form of a report. These reports

are, like all other data acquired by spies, biased and must be carefully scrutinized and the data in them used with discretion.

### Conclusion

*“The art of war is of vital importance to the State. It is a matter of life and death, a road either to safety or to ruin. Hence it is a subject of inquiry which can on no account be neglected.”*

The Art of War 1:1-2

War and cost estimation are both political tools. War is a tool that enables the state to extend its political will beyond its borders or to defend from the incursions of other states. Cost estimation is the process by which a state determines the level of resources required to achieve a political purpose. Strategy is the process that is employed to determine how political purpose is translated into action. One of the greatest enduring works on military strategy is The Art of War, which has influenced many generations of strategic thinkers. The Art of War has captured the imagination of the public and its lasting popularity can be attributed both to its own merit and the transferability of its strategic insights to a multitude of subject matters. This paper has sought to introduce core concepts of Sun Tzu’s strategic thinking and frame those concepts in cost estimating terms.

We have examine the five factors: the relationship between the program manager and the cost estimator (The Moral Law), uncertainty that surrounds the known and unknown (Heaven), the tools which are employed to develop cost estimates (Earth), the cost estimator themselves (Commander), and the logistical foundation upon which the cost estimate is constructed (Method and Discipline). The cost estimator must understand and master the five factors in order to develop credible cost estimates.

Sun Tzu highlighted the five essentials of victory; those characteristics of the general and the army that will determine who will emerge victorious in conflict. The concept of victory in battle can very aptly be equated with the cost estimating concept



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of credibility (the “correctness” of an estimate is not a measurable metric). The first essential is knowledge of when sufficient data is available to develop a cost estimate that can be considered credible. The second essential is knowledge of how to handle data of all kinds, be it good data (normalized, analogous and within the predictive range) or poor data (inconsistent, non-similar or old). The third essential is forming strong interpersonal relationships within the cost estimating team and the rest of the program office as well as reinforcing the need to maintain high morale. The fourth essential is to be prepared; be ready to answer questions about the cost estimate and tailor the documentation to address the concerns of the reviewing leadership. The fifth and final essential is for independence from interference from the program manager and other non-cost estimating supervisory bodies.

Sun Tzu’s pragmatic metric of superiority is a ratio of payout to investment. In cost estimating terms this equates to which cost estimating methodology (analogy, parametric, engineering build-up or actuals) will result in the most credible estimate for the lowest amount of cost estimating resources (mostly measured in time). The methodology that can achieve the highest ratio (this metric is highly subjective) is heavily dependent on when in the program life cycle the cost estimate is being developed. In the operations and sustainment phase the actuals cost estimating methodology would have a significantly higher credibility to time ratio than an estimate built using the analogy method. In a less straight forward example, during the concept refinement stage of a program the determination of which methodology is superior, analogy or parametric, depends quite heavily on the level of readily available data. If there exists a database of relevant and normalized data from which to construct a CER, the parametric methodology will be able to build a cost estimate with a higher credibility to time ratio. However if there is no database of relevant data to work with, the analogy method comes out on top.

Sun Tzu believed that foreknowledge and how to gather it was the lynchpin of strategy. In Sun Tzu’s

terms this is accomplished through espionage; in cost estimating terms it is done through gathering reliable data sources. Sun Tzu identifies five different types of spies and cautions the reader that great care and subtlety must be employed when working with spies for it can be challenging to verify the truth of their reports. This is also true in cost estimating due to the biased nature of people as sources. All of the various types of spies (Local, Inward, Converted, Doomed and Surviving) are able to provide valuable information that can have significant impact on the cost estimate, but great care must be taken to ensure that the data that is received is credible.

Sun Tzu describes the ideal general, and the sum total of this description approaches the super human. The general must be strong and forceful yet also subtle and inscrutable; patient but quick to strike at opportunities; cautious and bold in equal measure. In the end, it is the striving towards a harmony between the conflicting interests that are found in all human endeavors that makes the capable general and by extension the capable cost estimator. Harmony must be reached between the program manager (whom the Moral Law dictates must be obeyed) and the cost estimator (who has the education and the skills to develop credible cost estimates). Harmony must be reached between the rigorous mathematical methods and disciplines and the uncertainties of Heaven. And harmony must be achieved between the human bias that so strongly informs cost estimates and the need to ground those cost estimates in unbiased methods to establish credibility.

On a personal note I hope that you have enjoyed reading this paper as much as I have enjoyed writing it. Constantly throughout the process of writing and editing this paper I have found myself questioning the analogies and the correlations between the strategies of war and cost estimating. This has been a process of self-discovery in building a personal philosophy of cost estimating. I hope that the concepts I have explored in this paper have been thought provoking for you, bringing to light new questions and perspectives. Perhaps you even disagree with some of my



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conclusions. Unlike the author of *The Art of War*, who asserts that Sun Wu is a master, I make no such claim of mastery. I will forever be learning. However, I think it is safe to say that cost estimating is not a science, it is an art.

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