The BS in BoeS

Oh, the Games That Are Played

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Table of Contents

Table of Figures

List of Acronyms

APR	Approver
BFO	Budget/Finance Office
BoE	Basis of Estimate
BS	Bias Selectivity
CE	Cost Estimator
CEO	Chief Executive Officer
CO	Contract Officer
DM	Decision Maker
ECP	Engineering Change Proposal
EP	Estimating and Pricing
FAR	Federal Acquisition Regulation
FE	Functional Estimator
FM	Functional Manager
FFRDC	Federally Funded Research and Development Center
Govy	Government Employee
ICE	Independent Cost Estimate
ICEAA	International Cost Estimating and Analysis Association
ME	Mission Effector
MR	Management Reserve
O&M	Operations and Maintenance
OCI	Organizational Conflict of Interest
OEM	Original Equipment Manufacturer
PM	Program Manager
R&D	Research and Development
RFP	Request for Proposal
SETA	Systems Engineering and Technical Assistance contractor
US	United States
WBS	Work Breakdown Structure

Prologue

The young engineer stopped to watch the evening thunderstorm. Outside the rain washed some of the oppressive southern summer air away. Inside the modern office building, the air conditioning chilled the few remaining occupants. The engineer looked back at the computer monitor to finish updating the last of the BoEs. It had been a long three weeks. The engineer reflected upon the memory of the boss coming into the vast corporate office cubical space with this BoE assignment to this southern hinterland office. The boss had told the young engineer not to worry about never having written a BoE before, as it would be a simple stretch assignment. This assignment with its 12-hour days had been anything but simple. The only activity that made this assignment bearable was the nightly trip to the beverage establishment that contained 40 flavors on tap and 300 bottles scattered around the rooms. The engineer finished the last BoE update, turned off the computer, and walked toward the exit, thinking about what flavor to try tonight. Approaching the exit, the engineer passed the normally locked door to a special room. The door was open with bright lights and a lot of activity within. The engineer was glad to not be one of those “pricers” working in that special room. The young engineer knew that they would be up all night to incorporate all the BoE changes, just completed, and publish the final cost volume to be delivered tomorrow.

Basis of Estimates (BoEs) Are a Story

So, why does a paper on BoEs start off sounding like a short story? The reason is to emphasize that a good BoE should be crafted like a well-constructed story that leads the reader step by step from the beginning to the end. The story should be logical, without plot twists and math errors, and should lead to a simple conclusion. To emphasize that a BoE should be a story, this paper is purposely constructed in story form, with a prologue, chapters, and an epilogue. As part of a good BoE story, the BoE writer must clearly present an acceptable estimating methodology and its supporting data. A BoE should also be considered a sales brochure that entices the buyer to purchase your product. A “glossy” BoE may have fancy statistics and sound historical data that proclaims a great result, but the buyer still needs to consider the seller’s agenda, contained within the BoE. The next section describes the BoE agenda – the BS.

Disclaimer

This paper presents observations, analysis, and opinions of the author only, and does not claim any endorsement or agreement from the author’s previous, current, or future employers. This paper considers all mentioned persons performing their job to be hard-working good employees. Any job function that appears to cause conflict should not be considered bad, but should be looked at as reflecting differing institutional or organizational incentives. If there were no conflict or differing incentives between the various job functions described within this paper, there would be no games to be played or reason to continue this discussion.

Bias Selectivity (BS)

The lurking sales part of a BoE is the BS in the title of this paper, which is defined as Bias Selectivity. Bias Selectivity is not an official statistical term but is defined in this paper as the systemic favoritism injected into the BoE by the author’s choice of such elements as a particular program, comparable to the proposed program, from which historical data can be drawn; the program’s period of performance; any complexity factors; the use of engineering judgment; and/or any other estimating methodology to develop the BoE’s work scope estimate. In simple terms, the BoE author fits the estimate justification to the author’s preferred outcome by selectively choosing the justification inputs. Bias Selectivity is not bad – it is just part of a sales strategy. The buyer, also having a strategy, should be aware of the seller’s potential strategies. Hence, when two players – a buyer and a seller – employ strategies, game playing occurs.

This paper will attempt to explain why and where Bias Selectivity appears in most but not all BoEs. A BoE, at its core, is a written explanation of a seller’s estimated cost to a buyer. If a buyer selects the seller’s proposal, negotiations usually follow, focusing on the costs estimated in the seller’s BoEs.

Markets where sellers provide BoEs to buyers tend not to be for commodities but rather for complex programs, hence the opportunity for negotiations.

This paper focuses on the unique government market for non-commodity products. In this market, the government is the sole buyer, and it procures products and services under specified rules and regulations. The sellers of products and services in this paper are Original Equipment Manufacturers (OEMs). The paper also looks at the buying and selling of intragovernmental budgets. In all cases the buyer requires the seller to provide some type of BoE that will be used for some type of negotiation between the buyer and seller.

Frequently,[1] in the government market a negotiation takes place between the buyer and seller, setting up the conditions for game-playing behavior, as described by John von Neumann (1903–1957). This paper will demonstrate how BoEs are used in the game playing between the buyer and seller. Bias Selectivity in the seller's BoEs plays a role in this game.

Prior BoE research by the International Cost Estimating and Analysis Association (ICEAA)

In the OEM world BoEs play a significant role, as they are a key input to the OEMs' pricing process for proposals to obtain new government contract work. A search through the ICEAA archives from 2007 through 2021 found only nine presentations and no written papers on the topic of BoEs. A summary of these nine presentations appears below. One presentation, by Frank R. Flett in 2016 (Number 6 below), is relevant to this paper. Mr. Flett's presentation emphasizes impression management for BoEs. He presents two cardinal rules: "Never Make an Evaluator Work!" and "Never Make an Evaluator Think!" Three of the nine presentations argue for using parametric tools in writing BOEs, three presentations provide mythologies for reviewing BoEs, and the three remaining presentations respectively offer a tool to help write a BoE, discuss how to write a schedule BoE, and describe how to use better organization and word choice in a BoE.

1. "A Basis of Estimate (BOE) Tool for Project Estimates," Bob Fairbairn, James Miller, and Rosemary Baize, 2008. A presentation of a BoE tool developed at NASA for use in formulating and documenting project build-up estimates as part of an effort to improve the quality and documentation of proposals.
2. "Risk Based BOE Analysis – PMAG Approach," Imran Ahmed, David Wang, and Mun Kwon, 2010. A presentation on a top-down approach to analyzing OEM BoEs.
3. "Time Is Money: The Importance and Desired Attributes of Schedule Basis of Estimates," Justin Hornback, 2013. Applying cost BoE properties to schedules.
4. "Analysis of Large O&S Proposal: Lessons Learned!" 2013. A presentation on the process used and the lessons learned by the evaluation team of an OEM proposal.
5. "BOE Development: Scope Evaluation and Criteria," Michael Butterworth and Demetrius Prado, 2014. A presentation focusing on improving the BoE process and the criteria for grading BoEs.
6. "Footprints in the Sand: A Conversational Approach to Basis of Estimate," Frank R. Flett, 2016. A presentation giving tips on writing more persuasive BoEs.
7. "Generating a Semi-Automated 'Similar To' Basis of Estimate from a Complex Parametric Hardware Cost Model for Antennas," Danny Polidi and David Bloom, 2016. A presentation that discusses the development of a "Similar To" BoE generation tool used in conjunction with a complex parametric antenna cost model.

[1] Even when a government agency buys off a government catalog, usually the agency creating the catalog has negotiated with the seller for some type of discount. The cases where emergency executive powers are invoked to procure goods and services without negotiations probably border on violations of government procurement rules.

8. “The Journey from ’Bottom-up’ to Predictive Modelling BOE,” Lori Saleski, 2017. A presentation by an OEM that looks to using a parametric COTS tool for BoEs instead of traditional methodologies.
9. “The Beginning of the End of Traditional Analogous ‘Bottom-up’ Estimating,” Chris Price, 2019. A presentation on the benefits of using a parametric tool for BoEs instead of the traditional approaches.

The Protagonists: Govy, SETA, OEM

Like a good story, this paper has three protagonists: the Government Employee (Govy), the Systems Engineering and Technical Assistance contractor (SETA) and the OEM. These labels are not meant to be pejorative, but are simply a means to model the three key players in the government procurement game into representative categories. The Govy, generally, plays the buyer, with support from the SETA, and the OEM plays the seller role.

Any person employed by a governmental organization falls into the Govy category. SETAs encompass all the traditional SETA companies, Federally Funded Research and Development Centers (FFRDCs), tool providers (such as the esteemed ICEAA sponsors), and consultants. The OEM category contains all companies trying to provide goods and services to the government. Since OEMs create the bulk of the detailed and complex BoEs submitted to the government as a buyer, this paper gives them top billing over companies that are predominantly labor service providers. Although SETAs are service providers, they play a special role in the procurement game that will be further detailed in their own chapter.

Protagonists Are Vectors

This paper uses concepts of game theory, which is a branch of mathematics, throughout. In addition, it needs some enhanced math bona fide, accomplished by establishing the three protagonist categories as multidimensional vectors. In other words, the Govy is not a monolithic worker, but a vector of many different types of workers, denoted by subscripts. The Govy can be expressed as a function of its elements, e.g., Govy = f($Govy_{DM}$, $Govy_{ME}$, $Govy_{PM}$, …). A list of all the vector definitions will be found at the beginning of each chapter for that vector type.

The paper begins with the Govys and continues with a short chapter on the SETAs, followed by a description of the complex OEM gamesmanship. The epilogue summarizes the discussion and recommends some ways of reducing Bias Selectivity and improving BoE quality.

Let the Games begin!

Chapter 1 – The Govy

Based on the number of BoEs it reads versus the number of BoEs it creates, the government mostly acts as a buyer in the procurement game. However, within the government, a significant amount of buying- and selling-like activity occurs between different governmental organizations. Two categories of goods are being bought and sold: budget requests, and authorizations for procuring Research and Development (R&D), Production, and Operations and Maintenance products and services from OEMs. This chapter will first discuss the intragovernmental BoEs and their game play, and then the Govy's role in reviewing OEM BoEs.

The Govy vectors:

$Govy_{APR}$ – Approvers: this large group includes elected members of Congress, their staffers, the professional committee staffers, and the congressional researchers and auditors.

$Govy_{BFO}$ – Budget/Finance Offices: the offices responsible for creating and managing a government agency's budgets and finances.

$Govy_{CE}$ – Cost Estimator: a government employee, working in a budget or program office, who is educated and trained in the disciplines and methodologies required for cost estimating.

$Govy_{CO}$ – Contract Officer (CO): a government employee who oversees the procurement and execution of government contracts. The CO has the sole authority to award and issue contract modifications.

$Govy_{DM}$ – Decision Maker: any government person who approves budget requests and/or authorizes funds.

$Govy_{ME}$ – Mission Effector: the footwear-on-the-ground Govy who executes a government agency's mission. This includes military soldiers, airmen, and sailors; Social Security claims representatives; and tax auditors.

$Govy_{PM}$ – Program Manager: the person responsible for executing an authorized program.

Budget Formulation and Approval

The most common type of BoE created by a Govy is a budget justification for use in the budget formulation process, which is an annual event for the US government. Typically, budget formulation starts at low levels of an agency, with each level of the organization trying to sell its budget request to the next-higher level. The budget formulation process within the government often includes the gamesmanship of the requesting (seller) organizations asking and justifying requests for sums greater than their needs, knowing that the approvers (buyer) will not budget them for their full request. Since this is a repeatable game, the buyers know that the sellers are asking for more than they need in their budget justification documents. This game gets resolved in the end by collaboration between the $Govy_{BFO}$s and $Govy_{Dm}$s, based on politics, policy, and the $Govy_{BFO}$'s evaluation of all the budget justifications.

How much Bias Selectivity goes into these budget justifications? Somewhere between none and a lot. When an agency requests a budget large enough to cover only its authorized staffing needs, then no bias will be present in its justification. When an agency requests a significantly increased budget over its previous year's budget, then the justification may contain Bias Selectivity or optimistic assumptions. It is up to the $Govy_{BFO}$s and $Govy_{DM}$s to decide how much of this increase to include in the final budget formulation.

In the US, after Executive agencies have completed the budget formulation process, the government budget goes through the process of approval by the $Govy_{APR}$s. This process requires a congressionally approved appropriation and agreement by the President. This process involves professional

congressional staffers, researchers, auditors, and, of course, the elected members of Congress reviewing submitted budget documentation, analyzing non-budgetary data, and reading polling data to modify the budget submittal to their preferences. During the approval process, negotiations between the $Govy_{APR}$s and the ultimate $Govy_{DM}$ occur until an agreement is reached.

The budget formulation and approval process can be characterized as a multi-player, repeatable, non-zero-sum game, where there is no equilibrium solution. It is unlikely that negotiations between the $Govy_{APR}$s and the $Govy_{DM}$ involve disagreements on the routine operational BoEs contained in budget documentation. Disagreements arise over the estimates for large new investments in R&D and expensive production items. A discussion of the BoEs for these expensive items follows in the next sections.

Cost Estimates for Large Budget Items

In the budget formulation process, it is large new investments in R&D and the procurement of expensive production items that particularly attract attention – specifically, as to the validity of their cost estimates. The cost estimates for these expensive items are usually performed by a dedicated staff of trained cost estimators, which are denoted as professional $Govy_{CE}$. Often for these high-valued cost estimates, the government will procure SETA support to augment their staff of $Govy_{CE}$s. The professional $Govy_{CE}$ will use available historical data and various analytical techniques to formulate the budgetary cost estimate. These estimates are usually done at high levels of the product's work breakdown structure (WBS), since that is the level of detail contained in their data sources. Interestingly, the $Govy_{CE}$ can perform more accurate cost estimates than their OEM counterparts at this phase of requirement specificity, since the $Govy_{CE}$ has access to cost databases covering multiple OEMs, such as the Cost Assessment Data Enterprise (CADE) database.[2] As part of doing these cost estimates the $Govy_{CE}$ may develop a "should-cost" model for use in negotiating the budget request and for later use during the procurement process after budget approval. However, sometimes the $Govy_{CE}$ may not understand the technical and schedule challenges in their unbiased cost estimate.

The game that is played during this formulation process primarily involves underestimating the true expected costs, since $Govy_{DM}$s may be concerned that too high a cost will lead to non-acceptance by $Govy_{APR}$s. Does this mean that there is Bias Selectivity in the BoEs for these cost estimates? Not necessarily, as there are multiple ways to underestimate the costs: assumptions that are too optimistic or pessimistic; immature requirements; and lack of similar-to historical data. These three potential problems are inherent in BoEs for large new investments in R&D, since what is being estimated is mostly just a concept. The James Webb Space Telescope is an example of gamesmanship via underestimating the technical complexities, as the original cost estimate of $1.6 billion has grown to an actual cost of almost $10 billion today after finally launching.

Procurement Support

After budget approval, the government is allowed to begin the process of buying goods and services. For simplicity this paper uses the term OEM as the seller to the government of goods or services. The vast majority of procurements to the US government are for relatively small dollar values. In government fiscal year 2021, 5,549,307 contracts were awarded to business.[3] Of those awards, 98% were for less than one million dollars, and 92% were for less than one hundred thousand dollars. While some game playing may occur with these small-dollar-value contracts, the interesting analysis and game playing occurs in the higher-value contracts; in fiscal year 2021 there were only 9,126 contracts awarded for greater than 25 million dollars, or 0.16% of the total. Many of these large-value contacts are sole sourced to one OEM. This occurs when the $Govy_{CO}$ can justify the conclusion that only one OEM can provide that product or service at a reasonable cost. Sole source procurement will be examined from the OEM perspective later in the OEM chapter.

[2] For more information see the following web site: https://cade.osd.mil/.
[3] Data from US government web site: https://www.usaspending.gov/search.

For a high-value competitive procurement, the $Govy_{CE}$ supports the $Govy_{PM}$ and $Govy_{CO}$ in preparing the formal Request for Proposals (RFP) and reviewing the submitted proposals. During the RFP preparation, the $Govy_{CE}$ may include instructions in the RFP as to the level of the WBS the OEMs should use in constructing their BoEs. However, this situation does not occur often. It is during the RFP evaluation phase that the $Govy_{CE}$ provides the most support to the procurement process. The $Govy_{CE}$ gets the pleasure of reading and evaluating the OEM BoEs for reasonableness. Often the $Govy_{CE}$ is supported by a SETA contractor, as discussed in the next chapter.

During the RFP evaluation phase, not much game playing occurs due to the Govy's role in reading and evaluating BoEs for reasonableness. Sometimes during this phase, however, a significant game is played between the $Govy_{CO}$ and the $Govy_{PM}$ in which the $Govy_{CE}$ plays the honest broker. This game takes two different forms, depending on if the procurement is competitive or sole source. In a competitive procurement, this situation occurs when the $Govy_{CO}$ wants to award a contract to a lower-priced proposal that the $Govy_{PM}$ thinks will not meet their needs. In a sole source procurement, this conflict can take the form of not being able to reach a contract agreement during negotiations.

The root cause of this conflict between Govys is a differing of personal incentives. Sometimes the $Govy_{CO}$ is evaluated and promoted based on their ability to obtain the lowest price or negotiate large reductions in price during contract negotiations. The $Govy_{PM}$, on the other hand, is incentivized to deliver their program capabilities at or under budget. In a competitive evaluation, the $Govy_{PM}$ may prefer a higher-priced proposal over the lowest-price proposal that is preferred by the $Govy_{CO}$. The $Govy_{PM}$ may believe the higher-priced proposal carries less execution risk and provides significantly more capabilities for the extra price. Ultimately, this is resolved by the source selection authority, an executive $Govy_{DM}$. In a sole source negotiation, the $Govy_{PM}$ may want to settle quickly to begin execution due to a crucial need, while the $Govy_{CO}$ may want to continue negotiations to extract more cost concessions from the OEM. Again, an executive $Govy_{DM}$ will make the final decision.

This intragovernmental game can get more complicated when the $Govy_{ME}$s disagree with what the $Govy_{PM}$ wants to procure for them, meaning that the requirements in the RFP do not satisfy the $Govy_{ME}$s' needs. Unfortunately, this misalignment of needs happens when the $Govy_{PM}$ is biased by outdated knowledge, budget constraints, or external influences. When the $Govy_{MEs}$ have a strong advocate in the procurement process, their critical needs will be included in the final contract.

In this chapter about the role of the Govy we have observed only modest Bias Selectivity, mostly occurring during budget formulation, and game playing primarily occurs between Govys.

Chapter 2 – The SETA

The role of the SETA requires less elaboration. SETA companies, FFRDCs, and firms providing specialized analysis tools have been formed to be professional independent expert advisors. As an advisor, a SETA has no decision-making responsibilities. SETA analysts may incorporate some Bias Selectivity into the cost estimates they provide. However, this Bias Selectivity becomes the responsibility of the organization that hired the SETA, since the hiring organization is the cost estimate owner. Since there are no differentiating elements within the SETA, the vector contains only one element.

The single element SETA vector:

SETA – A person or organization that provides analysis and engineering services. Since cost estimation is part of the Systems Engineering discipline, companies that specialize in providing cost estimation support to the government are SETAs.

The SETA Role

A SETA primarily supports the Govy in developing requirements, creating RFP solicitations, and evaluating submitted proposals. This support can range from small to significant. The Govy uses SETA advice to develop requirements, prepare RFPs, and/or provide analysis during RFP evaluation. Sometimes a SETA may work for or with an OEM during execution of a contract, but not on a contract that may provide information leading to requirement development for future RFPs. In the past, OEMs had business units that primarily acted like a SETA company. These business units were generally acquired during past market consolidation of government contractors through mergers and acquisitions. Despite the firewalls set up by the large OEMs to prevent organizational conflicts of interest, the government encouraged the OEMs to divest these SETA-like business units. Today, a few legacy SETA-like contracts may exist in the OEMs' portfolios, with the bulk of SETA contracts going to external SETA services companies.

Govy organizations hire SETAs to help perform cost estimation with supporting BoEs that justify budgetary estimates when they have too few resources to do the work themselves. Since SETAs are independent experts, they have little incentive to insert Bias Selectivity into their estimates. Bias Selectivity may, however, be inserted at the direction of the Govy in support of the Govy budget game (see previous chapter on the Govy).

With respect to BoEs, the only game the SETAs play on their own account is the "gotcha" game. SETAs are hired to support the Govy review of OEM BoEs. To demonstrate their value SETAs can be aggressively critical of the OEM BoEs. As shown in the next chapter on OEMs, aggressive criticism of OEM BoEs is easy, like shooting the metaphorical fish in a barrel.

SETAs and Independent Cost Estimates (ICEs)

Sometimes SETAs are hired to perform an ICE by one Govy element to review a different Govy element's cost estimate. One purpose of the ICE review is to find any Bias Selectivity in the cost estimate and its BoEs. If the Govy element creating the cost estimate knows ahead of time that an ICE will be performed, a simple game may be incorporated into the cost estimate. Knowing that SETAs play the "gotcha" game, the Govy creating the cost estimate and BoEs may insert some small (red herring) errors into the estimates, hoping the ICE team focuses on these small errors and not on other more significant cost elements. Sometimes this game works, especially if it is not part of a repeated game between the same two Govy organizations (players). This game is also played by the OEM and will be discussed in the next chapter.

The SETA Acting Like an OEM

Finally, SETAs may act like OEMs when they are bidding on contracts for their services. For simplicity, this paper classifies a SETA as an OEM service provider when it is bidding on a new contract for its services. The SETA behavior in its BoEs for this instance will be discussed in the OEM chapter.

Chapter 3 – The OEM

OEMs produce the bulk of written BoEs in response to government solicitations or RFPs. Also, OEMs are in business to earn a profit. The OEM's profit incentive, the government's rules governing the acquisition process, and the organizational structure of the OEMs all cause game playing and the use of Bias Selectivity in OEM BoEs. It is time to "play ball."

The OEM vector:

OEM_{CE} – Cost Estimator: an OEM employee who is educated and trained in the disciplines and methods required for cost estimating. The OEM cost estimator may work in the Systems Engineering function, the Estimating and Pricing function, on a specific program, or in an overhead staff organization.

OEM_{DM} – Decision Maker: an OEM person, generally an executive, who has authority to commit the OEM to the terms of a submitted proposal or contract.

OEM_{EP} – Estimating and Pricing: an OEM employee that may perform cost estimation, pricing, or both functions in response to government RFPs.

OEM_{FE} – Functional Estimator: an OEM assigned to estimate a function's work scope in response to an RFP. A function is defined later in this chapter.

OEM_{FM} – Functional Management: OEM executives and managers assigned to lead functional organizations. They have the responsibility to ensure programs are fully staffed and performing to functional standards.

OEM_{PM} – Program Manager: the person responsible for the execution of an OEM program.

Functional vs. Program Organization

As stated above, the organizational structure of the OEM contributes to BoE game playing and Bias Selectivity. The two leading OEM organizational structures are **functional** and **programmatic**. A functional organization assigns resources (employees) to a specific skill category or function within an OEM. A functional organization is also called a matrix organization. The OEM_{FM} is responsible for staffing various revenue programs and other non-revenue work scope that leads to positive OEM profits. Examples of functional organizations are Systems Engineering, Mechanical Engineering, Software Engineering and Development, and Business Management. Some functions – for example, the Systems Engineering function – have multiple subfunctions such as Logistics, Configuration Management, and Modeling and Simulation. The OEM_{PM} function has a significant characteristic difference from the other functions, since it is responsible for delivering the OEM's key financial metrics, such as profit (or margin), revenues, sales, and awards. In a functional organization the OEM_{PM} does not own most of the resources supporting its operational needs, as these are owned by the OEM_{FM}. Development and manufacturing OEMs generally align in a functional structure.

In a programmatic OEM structure, the OEM_{PM} owns most of the staff supporting its program. In this structure the managers of different functional disciplines report to the Program Manager. Note that support functions such as Business Management, Human Resources, and Business Development still exist in this organizational construct. In either structure the term "owned" means that the management organization has direct authority to hire, terminate, promote, and review its employees. Service provider OEMs tend to align in a programmatic structure.

An OEM must weigh the benefits and costs to choosing either the functional or programmatic operating model. Operational efficiency is the key benefit of a functional organization, since resources can be matrixed. This happens when the OEM_{FM} can successfully allocate its resources to minimize program costs while delivering a quality product. On the other hand, a programmatic structure benefits from customer intimacy and employee cohesion. Employees tend to start with the program from the beginning and continue with the program either until it ends or until they transfer to another program. In a

programmatic organization the program personnel build strong relationships with the customer's staff, gaining valuable insights into their needs and wants for follow-on work during program execution. Since most of the employees work within the OEM_{PM}'s organizational chain, their goals become aligned with the goals of the OEM_{PM}. This alignment of goals and customer intimacy helps the OEM when it attempts to capture additional follow-on and new business with the same customer or in a similar market area.

These diverging costs and benefits present OEMs with a dilemma. On the one hand, operational inefficiency costs drive many manufacturing OEMs away from the programmatic structure. On the other hand, OEMs that are organized by functions incur an extra cost in capturing follow-on and new business, which can be described as a "functional dysfunctionality with respect to capture." This dysfunctionality, which can be attributed to a misalignment of goals between the OEM_{PM} and the OEM_{FM}s, contributes significantly to poor-quality OEM BoEs that contain Bias Selectivity. To be clear, neither of the OEM_{PM} nor the OEM_{FM}s are villains; it is the OEM's incentive system that drive this observed behavior, which ranges from mild to extreme.

To visualize functional dysfunctionality, follow these simple steps as shown in Figure 1. First place both hands in front of your face with your palms facing you. Next, align each hand's fingers upward, with your thumb tucked into your palms. Finally rotate your right hand 90 degrees and crisscross your fingers. The left hand (with the vertical fingers) represents the OEM_{PM}, who has profit, revenue, and award incentives. The right hand (with horizontal fingers that are orthogonal[4] to the left hand) represents the OEM_{FM}s, who are incentivized to deliver program execution under budget. The OEM_{PM} wants to create an affordable proposal to the customer by keeping costs low to maximize awards or new business. The OEM_{FM}s want the proposal to include costs as high as possible for their functional area, so they can deliver a large underrun on their execution budget. How this orthogonality of forces affects BoEs and causes game playing will be explored in the following sections.

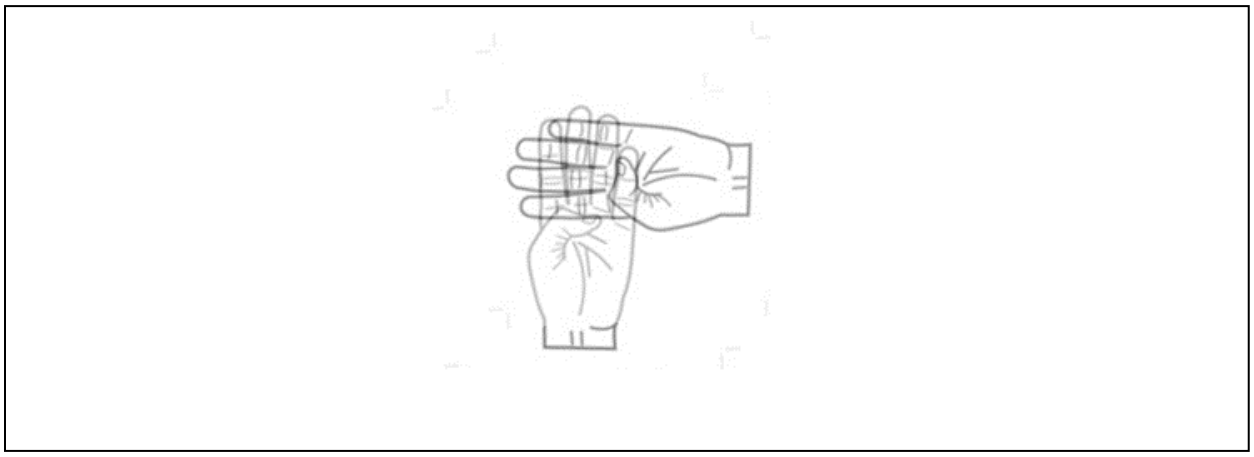

Figure 1. Example of orthogonal forces

Sole Source BoEs

In this section, assume the OEM is aligned functionally. In the government acquisition process, there are two distinct types of RFPs: sole source or competitive. A few of the rules applied by the Federal Acquisition Regulation (FAR) for submitting sole source proposals differ from those that apply to competitive proposals. In general, however, the process that OEMs use for responding to the RFPs do not significantly differ between the two proposal types. This section will explore the OEM process for developing sole source BoEs.

[4] Orthogonal is a mathematical term for perpendicular in multidimensional space.

FAR Section 15.403-4 requires OEMs to provide certified cost and pricing data in responding to high-dollar-value sole source RFPs. Far Section 31.205-7 on contingencies forbids OEMs to propose management reserve (MR) costs for most cost objectives in their proposals. The only exception is specified in FAR Section 31.205-7(c)(1).[5] This rule allows OEMs to bid quantifiably objective MR. An example would be an allowance for material scrap, which can be calculated from historical manufacturing costs. The inability to include MR for risk mitigation in proposals drives OEMs to include Bias Selectivity in their BoEs.

For the most part, OEM BoEs, using historical functional data, are developed by OEM_{FE}s that report to their functional organization, and approved by their OEM_{FM}s. It should be emphasized that the OEM_{FE}s try to find relevant similar historical data on which to base their estimate but sometimes fail. Several reasons contribute to the failure to use historical data in BoEs: (1) no data may be available from a similar project if the OEM is attempting to get into a new market; (2) the OEM_{FE} may take the easy path by asserting "engineering judgment"; (3) the OEM_{FE} may attempt to estimate costs in the proposed WBS at too low a level when all the historical data was collected at a higher WBS level;[6] and (4) a combination of the first three cases. These four reasons can be attributed to the OEM_{FE} estimating at too low a WBS level, since it may take many levels of WBS indenture (decomposition) to get to individual functional work scope.

To help clarify how OEMs estimate costs for a proposal, this section will use an example of an OEM bidding on the development of a hypersonic widget using a WBS, detailed in Figure 2, that contains 2 subsystems and 30 components. In this example, if the OEM estimated costs at the lowest indentured level there would be 34 BoEs – 30 components at Level 4 plus four Level 2 WBSs. However, a functionally aligned OEM will add at least one more WBS level in Figure 2 for each function that contributes to each of the 34 lowest indentured WBS lines. If each of these 34 WBS lines covered, on average, three different functions, then there would be 102 functional BoEs. The number of functional level BoEs can grow substantially as the complexity of the WBS grows.

WBS #	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
1.0	Hypersonic Widget			
1.1		Widget		
1.1.1			Subsystem W.1	
1.1.1.1				Component 1.1
….				
1.1.1.8				Component 1.8
1.1.2			Subsystem W.2	
1.1.2.1				Component 2.1
….				
1.1.2.6				Component 2.6
1.2		Propulsion		
1.2.1			Subsystem P.1	
1.2.1.1				Component 3.1
….				
1.2.1.7				Component 3.7
1.2.2			Subsystem P.2	

[5] FAR Section 31.205-7(c)(1) defines allowable MR costs as "[t]hose that may arise from presently known and existing conditions, the effects of which are foreseeable within reasonable limits of accuracy, *e.g.,* anticipated costs of rejects and defective work. Contingencies of this category are to be included in the estimates of future costs so as to provide the best estimate of performance cost."

[6] If the OEM_{FE} provides too many estimates at a WBS level that is lower than the OEM collected historical costs, then the OEM could have a compliance violation under Cost Accounting Standards 401.

1.2.2.1				Component 4.1
….				
1.2.2.9				Component 4.9
1.3		Systems Engineering		
1.4		Program Management		
1.5		System Test & Evaluation		
1.6		Support Equipment		

Figure 2. Example of hypersonic widget WBS with 2 subsystems and 30 components

The Figure 2 example WBS is based upon the United States Department of Defense *Standard Practice for Work Breakdown Structures*, also known as MIL-STD 881E.[7] The OEM_{FE}s face the challenge that the historical data that is available to them may not have been collected using a standard WBS such as the one in Figure 2. When historical data that the OEM_{FE} selects to use does not exactly align with what they are estimating, the OEM_{FE} must normalize the historical data, which involves making assumptions and choices. This normalization process is part of the "selectivity" in Bias Selectivity.

The bias in the OEM_{FE} estimate comes from the game played between the OEM_{FM} and the OEM_{PM}. The strategy or goal of the OEM_{FM} is to have an estimate large enough to be confident that the work scope can be executed for less than what was bid, meaning that the estimate should include some MR. For the OEM_{FE} to get estimate approval from the OEM_{FM} (their boss), they must find an estimate basis with some MR in it. The discussion above showed that functional estimating occurs at low levels of the WBS, so when all the functional estimates are added together, the MR from Bias Selectivity might be larger than necessary.

The Govys often criticize the OEMs for providing poor quality BoEs, giving several reasons for their observations. One criticism relates to the number of "engineering judgment" BoEs. This mostly occurs when the OEM_{FE} estimates a WBS element where the work scope is for a small number of hours, often as a result of estimating at too low a WBS level. An example of this would be a BoE for 26 hours that had a rationale for attending a one-hour weekly meeting with the customer over a six-month period of performance.[8] The next major contributor to poor quality OEM BoEs comes from the inexperience of the OEM_{FE}. The OEM_{FE} often is the most junior employee in the functional organization, since the more senior members get to prioritize their other functional activities over BoE writing. The senior functional members may provide suggestions to the OEM_{FE} on how to insert Bias Selectivity in the BoEs. The final common contributor to poor quality OEM BoEs is a lack of historical data. This mostly occurs when the OEM is bidding on developing new technology, or on applying capabilities the OEM has not supplied in the past. In this case the Govy might have better historical data to use for estimating than the OEM, as the Govy has access to cost data from all OEMs in a single database, such as the Cost Assessment Data Enterprise database previously mentioned.

After the OEM_{PM} receives the total cost from the OEM_{EP}, the functional estimates will be reviewed. In the sole source case, if the OEM_{PM} feels that this total cost is so high that it will tarnish the relationship with the customer, the OEM_{PM} will push back against the estimates to get the OEM_{FM} to agree to present lower ones. If the OEM_{PM} feels that the total cost is high but acceptable, they will choose to submit it as is, knowing that total costs will be reduced during the negotiation game with the Govy. Sometimes the OEM_{PM} arranges for an OEM_{CE} who is independent from the functions to assess the functional estimates. It may also be possible for the OEM_{PM} to use the OEM_{CE}s to estimate most or all the BoEs instead of using OEM_{FE}s. This case can occur under certain conditions, i.e., if enough OEM_{CE} resources and time are available, if OEM policies and culture allow for non-OEM_{FE} estimating, or if the OEM_{DM} overrides the OEM_{FM}'s objections.

[7] MIL-STD-881E, *Work Breakdown Structures for Defense Materiel Items*, 6 October 2020.
[8] Unfortunately, the author of this paper has seen way too many of these BoEs, and they are most likely a Cost Accounting Standards 401 violation.

After a sole source proposal is submitted, the negotiation game between the OEM and the Govy can take several forms. Often negotiations start with the OEM and Govy bargaining over every BoE. If the OEM has submitted a big stack of BoEs, then negotiations can take a long time. If time and negotiating energy begin to run low, the OEM and Govy will try to find methodology applicable to a higher cost level to finish negotiations. Finally, if negotiations get to an impasse at the working level, an OEM executive and a Govy executive will negotiate an agreement on a few top-line values.

Here are some of the gaming strategies the OEM may use, knowing that negotiations will commence with the Govy. If the Govy has limited time and resources, the OEM may choose to estimate at low levels of the WBS to overwhelm the Govy with BoEs. If this is a repeatable game, e.g., the first of many lot purchases, then the Govy may counter this strategy by specifying what level of the WBS they want to see in BoEs. If the OEM knows that the Govy and/or the Govy's SETA like playing the "gotcha" game as described in the SETA chapter, then the OEM may purposely insert errors or glaring overestimates in some BoEs that the OEM can knowingly sacrifice during negotiations. As stated in the Govy chapter, the OEM may be caught in the middle of a game between the $Govy_{PM}$ and $Govy_{CO}$. When this game becomes obvious, the OEM strategy is to try to raise the negotiations to the executive level as quickly as possible.

Competitive BoEs

Initially, for competitive RFPs functionally aligned OEMs tend to use an estimating process similar to the one they use on sole source RFPs. However, in a competitive environment there is another force that can drive OEMs to produce better BoEs. To illustrate this, reimagine from the section above (Figure 1) on functional organization that your hands and fingers are aligned in an orthogonal orientation. Then imagine an invisible pair of hands cupping over your hands and squeezing your fingers into a single ball. This forces your fingers (or vectors) to align more closely, as shown in Figure 3. This competitive force (cloud-like) is akin to Adam Smith's invisible hand.[9]

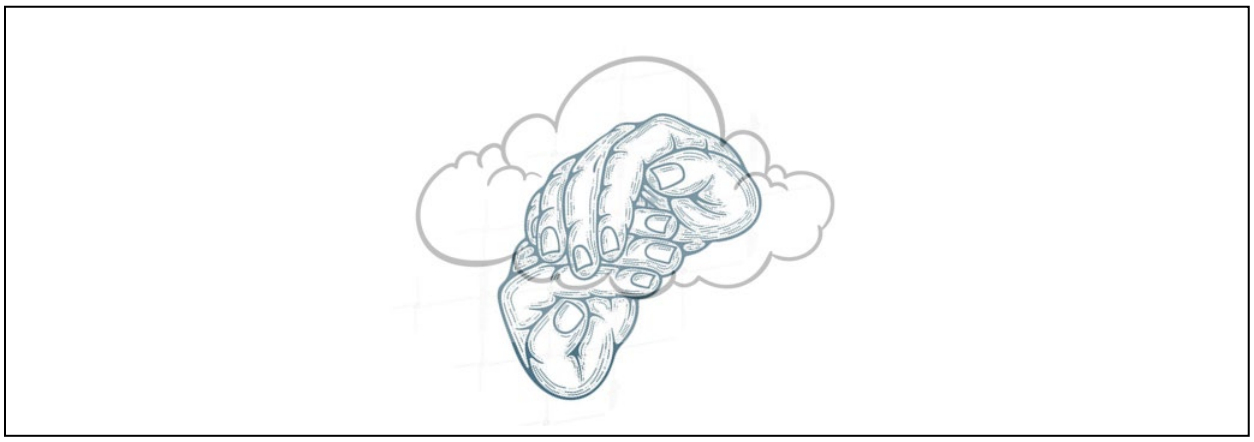

Figure 3. Example of competition aligning forces

Figure 4 below is an actual picture of cost proposals submitted by three different large manufacturing OEMs[10] on a competitive bid for a US Navy radar program. All three OEMs are functionally aligned and use a combination of OEM_{CE}s and OEM_{FE}s for their large RFPs. Divergence from sole source estimating begins with the elimination of the cost and pricing data requirement and the elimination of negotiations on proposed costs.[11] These two changes from sole source contracting encourage the OEMs to write BoEs at

[9] Smith, Adam, *An Inquiry into the Nature and Causes of the Wealth of Nations,* Vol. 2, 1778 (2nd ed.).
[10] The names of the OEMs have been obscured to protect the dignity of the Big Stack OEM.
[11] Sometimes on competitive awards the government will negotiate costs with the awardee over minor scope changes and ask for a lower fee percentage.

higher levels of the WBS.

Figure 4. Three post Proposals from large OEMs

Assuming the three OEMs in Figure 4 used a WBS similar to the one in Figure 2, the picture in Figure 4 implies that the "big stack" OEM estimated its BoEs at Level 5 or lower of the WBS, while the two "little stack" OEMs estimated their BoEs at higher WBS levels. The culture within each OEM defines whether the orthogonal functional force is counteracted by the competitive force, resulting in a proposal that is integrated across functions (little stacks), or the functional force is stronger than the competitive force, in which case the functional sole source process (big stack) dominates. The observed behavior in Figure 4 shows that the "big stack" OEM allowed the OEM_{FM} review to keep the additive MR embedded in the numerous low-level BoEs. For the "little stack" OEMs in Figure 3, the competitive force appears to have been stronger than the functional force, resulting in fewer BoEs. This does not mean that the "little stack" OEMs do not have piles of draft backup BoEs that are equal in size to the big stack OEM, but rather that they chose a methodology that supplied them with less BoEs to submit.

Some Bias Selectivity may appear in competitive BoEs, as the OEMs still need to include some level of MR in their RFP response. Since competitive BoEs are evaluated for reasonableness, the Govy and/or SETA review of the BoEs will not be scrutinized as much as sole source BoEs. It is assumed that competition will drive down costs. However, sometimes an OEM will try to play the Engineering Change Proposal game. This game occurs when an OEM sends in an RFP at below expected costs ("buying in") and tries to recoup costs and gain additional fees by submitting Engineering Change Proposals to the original contract. The Govy sometimes counteracts this game in their evaluation of cost proposals by risk-adjusting any proposals that seem to understate the Govy's cost assessment.

The OEM Executability Review

Some OEMs require an executability review by executives before they submit a proposal that commits them to contractually binding terms and conditions. To be effective, the review must be carried out by OEM employees who are independent from the proposal process and outcome. This review has the independent evaluators assess the likelihood that the BoEs and other costs, such as the Bill of Material, can be executed at a threshold profit level. This type of review can lead to a game – similar to the one that is played between the OEM_{PM} and OEM_{FM} – where the independent reviewers may suggest adding costs to the proposal to inflate the expected profits. In this case, the executives have an incentive not to be part of a review team for a program that has poor execution financials. The review teams suggest cost increases more often for sole source proposals than for competitive proposals, as the force of competition will again push back on suggested cost increases.

Epilogue

Summary

As our BoE story comes to a close, the three protagonists – the Govy, the SETA, and the OEM – have been actively writing, reading, and analyzing BoEs, while playing strategic games that further their self-interest. As part of the strategic game playing, Bias Selectivity is incorporated into BoEs. Bias Selectivity is neither good nor bad; it is just a tool used in a sales document to further the seller's objectives. Buyers know that the BoEs they read may contain some Bias Selectivity. Buyers must decide how much to accept based on their own analysis. It is in this context that the game between sellers and buyers commences.

This paper provides some additional observations about the differences between Govy and OEM cost estimating. The Govy estimates costs during the early concept and design phase of a program. These cost estimates can vary widely, as there are many unknowns. Rarely will a Govy suffer consequences for a cost estimate that was significantly wrong. The OEMs mostly estimate costs in response to an RFP[12] for a specified product or service. These estimates vary less, since they happen later in the program lifecycle. If an OEM cost estimate that becomes contractually binding ends up costing the OEM money because the estimate was too low, some of the OEM vector elements may lose their jobs. To end on a more positive note, the next section suggests solutions for improvement.

How to Reduce Bias Selectivity and Improve BoE Quality

This paper has highlighted the problem of Bias Selectivity and the games played in writing and reviewing BoEs. This story will end with some ideas on reducing Bias Selectivity and improving BoE quality. It should be noted that Bias Selectivity cannot be fully eliminated from BoEs, since there will always be game playing when noncommodity products and services are bought from a seller trying to maximize profits. These four suggestions, however, can improve BoE quality: (1) use professional cost estimators; (2) encourage estimating at higher levels of the WBS; (3) change the FAR to allow contingency or MR to be included in proposals; and (4) reduce OEM functional oversight of BoE inputs.

Use Professional Cost Estimators

Generally, the government and SETAs hire and train employees who perform cost estimation as their primary responsibility, and thus are considered professionals. Since there are few academic programs specifically designed to educate and train cost estimators, most estimators learn on the job, with some supplemental training. Some government organizations and many SETAs strongly encourage their employees to obtain cost estimating certification.

In the OEM world, there are far fewer professional cost estimators relative to the number of cost estimates produced. OEMs produce different internal and external cost estimates across their multiple functional organizations. Resource constraints prevent the OEMs from adequately training all the personnel involved in all the high- and low-level cost estimates produced. This becomes evident in the continual use of junior staff to write BoEs. A few large OEMs have solved this problem by installing a centralized cost estimating function, while the remainder rely on inexperienced functional estimators. OEMs would benefit from solving the resource misalignment problem by adding more professional cost estimators. The government could encourage OEMs to use professional cost estimators by including inducements to their use in RFP solicitations.

Encourage Higher-level Estimation

Estimating at higher levels of the WBS has multiple benefits that have been discussed above. This is an easy fix for the government to achieve. In final RFP packages the government can provide a WBS and specify at what level they want to see BoEs. With proper planning and discussions with all potential

[12] Sometimes OEMs provide a Rough Order of Magnitude (ROM) cost to the Govy in support of their budget planning process.

bidders, the government can develop a WBS structure and estimation level that represent a reasonable compromise across the potential bidders. If the government were to include these specifications in the RFP instructions, then large discrepancies in the number of cost volume pages submitted, as seen in Figure 2 above, would become far less likely.

Include Contingency or MR in Cost Proposals

Changing the FAR to allow contractors to bid contingency in their cost proposals would be a big change. This change would reduce the pressure on OEMs to include Bias Selectivity in as many BoEs as possible to allow for MR in execution. In fact, some non-US countries allow MR to be bid in their cost proposals. One simple way to make this change would be to align the contingency costs with the Risk Register. Cost estimates and their associated BoEs could be created for each major risk identified in the proposal. These costs could be included as contract options in the signed contract value, but not executed unless the risk occurs. Once the risk occurs, the $Govy_{CO}$ could execute the risk option value to the contract without having to negotiate an Engineering Change Proposal.

Reduce Functional Oversight

This last improvement can happen only if the OEM executive leadership implements a top-down cultural change to reduce the functional oversight of BoEs. This paper is not suggesting that functional input and review be eliminated, but that functional personnel work collaboratively with non-functional estimators to provide less biased BoEs.

The Last Game

Readers who are aficionados of game theory must be wondering why the most famous game has not been mentioned. This game is probably played out daily on cable TV on one of the many crime shows running 24 hours a day. Since this game, the Prisoner's Dilemma, involves two criminal suspects in two separate interrogation rooms, it is not applicable to BoE writers and this paper. It is unimaginable and unfathomable that honest, hardworking cost estimators could ever face the Prisoner's Dilemma game. However, if, as a cost estimator, you ever find yourself in an interrogation room about some cost estimate you provided, this author's advice; - Take the deal and blame your boss.