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Auction theory and its potential use in the Army aviation bonus system

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THESIS

AUCTION THEORY AND ITS POTENTIAL USE IN THE ARMY AVIATION BONUS SYSTEM

by

Tony Koplin Verenna

December 2007

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The United States Army is increasing its force by 65,000 troops over the next few years. Included in this increase are Army aviators. Retention of the current soldiers in uniform is becoming very difficult as the deployment schedule of the current Global War on Terrorism wears down the individual aviator. Army Aviation is included in this build up of forces, yet it must also compete with the amount of jobs becoming available as the baby boomer generation retires and leaves gaps in both the civilian pilot workforce for commercial airlines and also the United States Customs air inventory. This thesis will explore the Aviation Incentive program from its outset. It will then continue with a discussion of Auctions and Auction Theory. It will conclude with a game theory approach and other mathematical approaches on bidding in auctions. Combining Auction Theory with the mathematical approach provides the bidder in an auction a more educated decision in their bidding strategy. Utilizing Auctions for Aviator retention allows the Army to be more flexible in determining a value for a bonus rather than limited by the offer of a static amount which may or may not help with retention.

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AUCTION THEORY AND ITS POTENTIAL USE IN THE ARMY AVIATION BONUS SYSTEM

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Submitted in partial fulfillment of the
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ABSTRACT

The United States Army is increasing its force by 65,000 troops over the next few years. Included in this increase are Army aviators. Retention of the current soldiers in uniform is becoming very difficult as the deployment schedule of the current Global War on Terrorism wears down the individual aviator. Army Aviation is included in this build up of forces, yet it must also compete with the amount of jobs becoming available as the baby boomer generation retires and leaves gaps in both the civilian pilot workforce for commercial airlines and also the United States Customs air inventory. This thesis will explore the Aviation Incentive program from its outset. It will then continue with a discussion of Auctions and Auction Theory. It will conclude with a game theory approach and other mathematical approaches on bidding in auctions. Combining Auction Theory with the mathematical approach provides the bidder in an auction a more educated decision in their bidding strategy. Utilizing Auctions for Aviator retention allows the Army to be more flexible in determining a value for a bonus rather than limited by the offer of a static amount which may or may not help with retention.

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I would like to thank my advisors for making this process seem smooth and not as cumbersome as it seemed to me on day one of graduate school. I would also like to thank the Defense Analysis Department for providing excellent instructors and instruction throughout the program. My eyes have been opened to a whole new view of the world. Lastly, I want to thank my wife Suzanne for allowing me to pursue this opportunity to attend NPS. The sacrifices she has made and that our children, Adison and Alex, are now making, cannot be overlooked one bit. This was great family time that I will never forget and never take for granted.

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I. INTRODUCTION

A. BACKGROUND

Army aviation personnel inventories are not meeting the standard fill levels. Current bonus offerings aid in their retention, however, they do not solve the problem. Aviators are still leaving the service after their initial obligations in search of work with an airline or with United States Customs. The Bureau of Labor and Statistics predicts 14,000 pilot job openings by the end of 2008 related to the baby boomer generation (Dohm, August 31, 2000). Members of the baby boomer generation have reached a very important time in their lives – retirement. It is mandatory for pilots to retire at the age of 60. Given the toll of the current war on military aviators, especially Army fixed wing aviators; the civilian job market looks attractive.

There are many factors affecting aviator retention. In addition to pay and benefits afforded to Army Aviators through Aviation Career Incentive Pay (ACIP), Aviation Career Continuation Pay (ACCP), and free training, the Army has also resorted to recalling aviators from the retired population or aviators who had previously resigned to meet inventory quotas. Army flight pay has gone through many changes and has performed several roles, including affecting retention and compensating for hazardous duty.

B. PURPOSE AND OBJECTIVES

The purpose of this concurrent mixed methods study is to explore Auction Theory and apply it to the Army Aviator Bonus system using game theory and other mathematical strategies to inform potential bidders on their potential submitted bids. The first phase will be a qualitative exploration of Aviation incentives in the military by collecting data from pilot databases at the Department of the Army Aviation Branch. Themes from this collection will then develop into an auction theory model so that the research question can be tested with respect to bidding strategies for an aviator.

C. RESEARCH QUESTIONS

Should the Army reassess its Aviation Career Continuation Pay using Auction Theory? Currently, the Army offers ACCP to only select specialty aviators to fill certain retention needs. However, the Army continues to fall short of its personnel needs in these same specialty areas. The ACCP amount does not correlate to the existing need at any specific time. In FY2003, ACCP was terminated due to budget constraints and retention dropped as a result. Auction theory provides a way to optimize retention and minimize costs.

By researching this question, other questions will be examined. They include:

1. How did the Aviation incentive programs originate?

2. What would game theory or other mathematical strategies suggest to a bidder in an auction format?

I intend to utilize auction theory so that the Army can reassess the bonus payments to its aviators in order to equal that of the other services. In particular, the Army should offer bonuses to commissioned officers who will be in demand as the Army expands. A tool, such as auction theory, can be utilized to determine appropriate the bonus to offer a pilot.

D. THESIS SCOPE AND METHODOLOGY

The scope of this study includes: (1) the background on the current pilot situation, both Army and civilian, (2) an overview of historical purpose of ACIP and the current ACIP measures relevant today, (3) an overview of auction theory and its application as a framework for setting bonus values, (4) a recommendation for a solution to use in offering bonuses to Army pilots.

E. CHAPTER OVERVIEW

This thesis is divided into six chapters which provide a logical sequence in the analysis of Auction theory and its application to Army Aviator Bonuses.

Chapter I introduces and outlines the paper. It starts with a brief background of the issue at hand - Army Aviation Bonuses. The chapter continues with the purpose and objectives of the thesis followed by the research questions. The latter end of the chapter covers the thesis scope, the thesis methodology, and ends with the chapter overview.

Chapter II summarizes military compensation from the monetary and non-monetary perspective. This chapter continues with a brief history of Aviation Incentive pay and Bonus pay. The chapter ends by describing the current pay and benefits afforded to Army aviators.

Chapter III describes Auction Theory and its key terminology. The chapter will describe the four types of auctions and their key features. It will continue with a description of potential bidding strategies and end with an illustration of Auction Theory in practice and how to apply it to Army aviator bonuses.

Chapter IV will consider applying Auction Theory to aviator bonuses. This chapter will conclude with difficulties that would arise from using auctions for aviator bonuses.

Chapter V offers a mathematical approach to decide on an amount to bid and which auction is appropriate for the services. This chapter will encompass game theory and other mathematical strategies.

Chapter VI will conclude the research and offer recommendations towards using Auction theory as a possibility to determine Aviator bonuses in the Army to assist in retention.

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II. COMPENSATION OVERVIEW

> The compensation system has been described as the 'glue' that binds together the organization, its underlying personnel system, and the people who are drawn into the system. A compensation system should attract qualified people into the system, keep them there, motivate them, and manage their exit when it is no longer in the best interest of the organization or the individual that they should stay (Hogan, 2004, p 39).

The following describes the military pay and benefits afforded to the Military Aviator that affect the aviator's decision to stay or leave the service.

A. MONETARY COMPENSATION

The basic pay table consists of approximately 50 percent of the total cash compensation allowed to all service members. The table is broken down by rank for the enlisted soldier, the warrant officer, and the commissioned officer. It is further broken down into years of service. It does not compensate for experience or job title. It is solely based on rank and years of service (Hogan, 2004).

Military members are not all offered adequate housing conditions. Depending on the base/post assignment, quarters may or may not be offered. In the case where quarters are not offered, a Basic Allowance for Housing (BAH) is provided. This BAH allowance depends on rank and whether or not the service member has dependants. Also, each zip code or area throughout the world varies in the BAH offered. For example, a person at the rank of O-4 living with dependants in a high cost of living area, such as Monterey, CA, receives a BAH of $2327.00; in a different part of the country where the cost of living is not as high, such as Fort Rucker, AL, this same officer would receive $1,108.00.

Overseas tours receive a payment equivalent to the BAH, called Overseas Housing Allowance (OHA). In addition to BAH and OHA, a Cost of Living Allowance (COLA) is offered when the BAH and OHA rates are lower than the cost of living in a certain area.

Military members are also compensated monthly to offset ration expenses. This is called the Basic Allowance for Subsistence. BAS continues to be a military tradition of providing room and board (or rations) as part of a servicemember's pay. It is intended to provide meals for the servicemember. The monthly BAS rate is based on the price of food. Each year BAS is readjusted based upon the increase of the price of food as measured by the USDA food cost index. BAS rates differ between officers and enlisted. The 2007 BAS Rates are $279.88 a month for enlisted and $192.74 a month for officers.

Every service member, upon signing their initial contracts, knows the military provides a retirement system. This system consists of serving a minimum of twenty years of active duty or the equivalent through the reserves. It is a form of deferred cash compensation and “becomes 100 percent vested upon completion of twenty years of service, with no vesting before that, it is a dominant retention incentive for officers and enlisted members at about the tenth or twelfth year of service” (Hogan, 2004, p. 40). This is very important in an aviator’s decision to leave the service, as more civilian aviation companies are abandoning their pension plans to those who have retired.

B. NON-MONETARY COMPENSATION

The non-monetary compensation benefits the services provide should not be discounted. Full healthcare is covered through the TRICARE system. For minimal out of pocket expenses, the whole family of a service member is covered for both medical and dental expenses.

In addition to healthcare benefits, a military member or family member is entitled to services provided through the Commissaries, Exchanges, and the many programs offered through the Morale, Welfare, and Recreation (MWR) service. All these services are offered at a considerable discount from the civilian equivalency. Other service benefits include low-cost childcare, legal services, financial consulting and employment assistance for spouses (Filip, 2006).

The factor that becomes a tremendous benefit to a service member is tax exemptions. The pay factors described above are all taxed; however, the allowances described above are not taxed. Also, goods purchased at the Commissary or exchanges are tax-free. In addition, any pay that is earned in a combat zone becomes tax-free. Another favorable area of tax-benefits includes state taxes. Many states, such as Pennsylvania, do not mandate a servicemember to pay state taxes if their home station is not in Pennsylvania. Other states offer other incentives.

The last area that is important, yet not quantifiable, is personal satisfaction. The sense of duty, personal pride, confidence, and leadership values that the service provides cannot be taken lightly. In addition, the training provided, especially the pilot training, must be taken into account for compensation (Filip, 2006). According to MAJ James Yastrzemsky, the Aviation Branch Representative at the United States Military Academy (personal communication, October, 2007), the Army's flight school estimates that it costs approximately between $1.2 million to $2 million to fully train an aviator depending on which advanced aircraft the pilot flies. The advanced aircraft include the AH-64 Apache, UH-60 Blackhawk, OH-58 Kiowa Warrior, CH-47 Chinook, and a C-12 fixed wing.

C. ARMY AVIATION PAY AND BENEFITS PROGRAMS

The different services offer special pays and bonuses to various occupation-specific or location-specific programs; this thesis is solely looking at the special pays and bonuses offered to aviators.

1. History of Aviator Compensation

Crew Member flight pay was designed as extra pay for officers to compensate for the exceedingly hazardous nature of military flying. All existing flight pay programs today derived from the first legislative authorization of special pay for flying duty. "[F]lying duty was incorporated in the Act of March 2, 1913

(Army Appropriation Act of 1914), ch. 93 [Public Law 401, 62d Congress], 37 Stat. 704, 705 (1913), which gave Army officers detailed to 'aviation duty' as 'actual flyers of heavier than air craft' an increase of 35 percent in their pay and allowances" (Curtis & United States. Office of the Under Secretary of Defense (Personnel and Readiness), 2005, p. 282). The initial years of this incentive categorized aviators as military aviators, junior military aviators, and aviation students. Each class of aviator had its own additional pay percentage of 75, 50, and 25 percent, respectfully, of their base and longevity pay. When the Army created the Air Service in 1920, the aviator class system was disbanded and all aviators were entitled to an increase of 50 percent in base and longevity pay. The other services, Navy and Marines, followed suit and in 1922, the Joint Service Pay Readjustment Act of 1922 established a uniform flight pay rate (Curtis & United States. Office of the Under Secretary of Defense (Personnel and Readiness), 2005).

It was not until 1948, at the request of the Secretary of Defense, that an Advisory Commission on Service Pay conducted the first comprehensive study of the military pay system since 1908. In reviewing the flight pay program, the commission concluded that, although special pays such as flight pay had been designed in part to compensate for arduous and hazardous duties, their main purpose should be to fill a supply and demand function while inducing personnel to enter upon and remain in hazardous military occupations. This Commission's recommendations led to the hazardous duty incentive pay provisions of the Career Compensation Act of 1949. This act is the basic source of the existing crew member flight pay authority; however, this was amended by the Career Incentive Act of 1955. This amendment introduced longevity step differentials based on years of aviation service with respect to rank rather than rank by itself. This developed into what is known today as aviation career incentive pay (Curtis & United States. Office of the Under Secretary of Defense (Personnel and Readiness), 2005).

> The Aviation Career Incentive Act of 1974 (1) established a system whereby an officer involved in the "frequent and regular performance of operational or proficiency flying duty" under competent orders was entitled to continuous aviation career incentive pay independently of whether, during any given year, the officer was actually assigned to flying duty; (2) set ACIP rates based on the length of an officer's aviation service rather than on grade and total military service, although years of officer service were used in determining such rates for more senior officers, i.e., those with more than 18 years of officer service; (3) set the highest ACIP rates for the years immediately following the completion of an officer's first obligated tour, which normally coincided with the retention-critical, flight-intensive, period of a career; (4) provided for the progressive phasing out of ACIP entitlements in the senior, less-flight-intensive years of a commissioned career, with total elimination of ACIP entitlements after 25 years of officer service; and (5) replaced the former "excusal" system with a set of operational flying-time standards, or "gates," for entitlement to continuous monthly ACIP (Curtis & United States. Office of the Under Secretary of Defense (Personnel and Readiness), 2005, p. 321-322).

The ACIP system remained unchanged until 1980, when the rates were increased 25 percent by the Military Personnel and Compensation Amendments. It was determined that the “need for and desirability of” the increases were paramount to improve retention. The retention problem was also addressed by the Department of Defense Authorization Act of 1981. This became the foundation for the Aviation Career Continuation Pay (ACCP). This payment consisted of up to four months’ basic pay for each year the officer agreed to remain on active duty beyond the expiration of his obligated service.

> Officers qualified for such pay had to (1) be entitled to ACIP under 37 U.S.C. §301a, (2) be in a pay grade below O-7, (3) be qualified to perform "operational flying duty," as that term is defined in 37 U.S.C. §30la(a)(6), (4) have at least six but less than 18 years of aviation service as an officer, (5) be in an aviation specialty designated as "critical," and (6) have executed a written agreement to remain on active duty in aviation service for at least one year. The aviation career continuation pay authorized by the provision in issue was in addition to any other pay and allowances, including

> ACIP, to which an affected officer might otherwise be entitled. Any agreement adopted under the provision in issue could not extend beyond the time an affected officer would complete 19 years of aviation service (Curtis & United States. Office of the Under Secretary of Defense (Personnel and Readiness), 2005, p 324).

Initially, ACCP was offered only to Navy and Marine Corps aviators because they were the only services experiencing retention problems at the time. The ACCP program was suspended for a short time and ACIP rates were increased, especially to those commissioned officers and warrant officers with more than six years of aviation service. This would target the population that would be entering the termination dates of their initial obligation. The National Defense Authorization Act of 1999 prescribed a single ACIP table for all officers that is relevant to the present. The National Defense Authorization Act of 2000 delegated to the services authority to offer a maximum of $25,000 to those officers whose skills are needed for retention. ACIP provides the incentive to perform a hazardous duty; whereas, ACCP serves as a financial incentive to retain qualified experienced aviators (Curtis & United States. Office of the Under Secretary of Defense (Personnel and Readiness), 2005).

2. Aviation Career Incentive Pay

ACIP, for officers and warrant officers, is based on years of aviation service, not years of active commissioned service. The following stipulations apply to receive this pay: to receive continuous flight pay through 18 years of service, a pilot must accrue 8 years of operational flying by the 12^{th} year of aviation service; to receive continuous flight pay through 22 years of service, a pilot must accrue 10 years of operational flying by the 18^{th} year of aviation service; to receive continuous flight pay through 25 years of service, a pilot must accrue 12 years of operational flying by the 18^{th} year of aviation service. The following table, Figure 2.1, shows ACIP (Vinch, 2007).

Years of aviation service (including flight training) as an officer:	Monthly rate
2 or less	$125
Over 2	$156
Over 3	$188
Over 4	$206
Over 6	$650
Over 14	$840
Over 22	$585
Over 23	$495
Over 24	$385
Over 25	$250

Figure 2.1. ACIP

3. Aviation Career Continuation Pay

By law, each service can offer up to $25,000 per year through the 25th year of commissioned service. The only Army specialty offered the full $25,000 is the Special Operations Aviator. The rest of the Army's warrant officer population is not entitled to the full amount, yet shortages are still present amongst other critical skilled aviators. The three components of these specialties include tactical operations officers, maintenance test pilots and maintenance test flight examiners, and special operations officers (Vinch, 2007). The current personnel strength of the tactical operations officer throughout the Army is at 55% and the maintenance officers average 82% strength between the two specialties (*Army aviation FY07 aviation continuation pay (ACP) program,* 2006). These three skill specialties are only allowed a maximum of $12,000 for extending their current contract by three years. The amount offered ($12,000) is not based on a certain percentage. There are two amounts offered in the Army, $25,000 for Special Operator aviators and $12, 000 for all others.

Although ACCP is designed to address retention needs; it does not seem to reflect current specialty needs. The other services allow the full amount for most job skills and decrease the amount according to their retention needs. For example, the Navy offers all pilots and naval flight officers $25,000 a year if they sign a five year contract that starts at the completion of their initial obligation (Vinch, 2007). The other three services are unique in that they do not have a warrant officer population. Their officers serve all the roles of an aviation community.

Although the Army is unique, the requirements of flying are not different from any other service member or Army warrant officer. The Army commissioned officer performs the additional job titles of leader, commander and staff officer. The Army has deemed the warrant officer as the technical aviation specialist. The Aviation commissioned officer is currently not a retention priority and thus, is not afforded an opportunity for an ACCP entitlement (*Army aviation FY07 aviation continuation pay (ACP) program,* 2006). Overall, "the Army currently projects a [commissioned] officer shortage of approximately 3,000 officers in FY2007, a situation that worsens to 3,700 officers in FY2008 and continues to average more than 3,000 annually through FY2013. This could result in 15% to 20% of all positions at the rank of major being vacant or filled by more junior and less experienced officers" (Henning & Library of Congress. Congressional Research Service, 2006, p. 1). These percentages reflect all branches of the Army, not just Aviation.

The Army's ACCP program for FY99 through FY06 was successful in decreasing loss rates and increasing warrant officer aviator inventory in all targeted MOSs; however, there still remains a shortage in the required inventory.

To bolster the inventory, the Army has recalled aviators from retirement or voluntary resignation, but that has been insufficient. Over the last four years, the ACCP has been applied at the 7 to 14 year mark of service, while flight schools have increased their production to meet requirements. Despite stabilizing the retention of officers offered the ACCP, the Army continues to experience shortages. According to Section 4 of the Army's Justification Book, 795 aviators received ACCP for FY 2006. The Army estimates that number will increase to 2,268 aviators by FY 2009 for total amount of $27,213,000 (*Department of the Army: Fiscal year (FY) 2008/2009 budget estimates,* 2007). This amount is small compared to overall budget (.02%); however, it is nearly a three-fold increase in the funding used to retain officers, and projections of inventories are still uncertain.

In FY 2003, the Army did not offer any ACCP contracts, due to budget constraints, and consequently inventories decreased. Although inventories increased in FY 2004, it is hard to judge the cause due to the STOPLOSS policy (*Army aviation FY07 aviation continuation pay (ACP) program,* 2006). STOPLOSS is a policy provided commanders to alleviate any shortages of personnel. Basically, no one is allowed to leave the Army via resignation and retirement. This policy can be initiated any time when inventories become critical; however, the program should not be used as a retention tool. Pilots who are forced to stay in the service after they have decided to leave by way of retirement or resignation tend to be disgruntled. Most officers affected by a STOPLOSS policy had fulfilled their contractual services and were eagerly looking forward to their lives outside the Army. Overall, this could affect the safety of flying aircraft. Pilots need to be focused on their flight and not be concerned about a STOPLOSS program.

The growing requirements of aviators and the budget demands of war could strain the ACCP system in the future; however, one way to optimize retention through the ACCP program may be to utilize Auction Theory. Everything in life comes with a price and the value of something to different individuals may vary.

III. AUCTION THEORY

A. INTRODUCTION

According to Herodotus, auctions existed around 500 B.C. in Babylon, where once a year women of marriageable age were sold on condition that they be wed" (Cassady, 1967). This occurrence is the first known and documented auction of any kind. The ancient Romans also used auctions in commercial trade and stake claim to have held the most preposterous auction in history in 193 A.D. The whole Roman Empire was placed up for auction after the Praetorian Guard killed the preceding emperor, Pertinax. Didius Julianus outbid everyone to claim the emperor's seat; however, he was beheaded only two months into his legacy and eventually the Roman Empire was given back to the people (Cassady, 1967).

Auctions made their way to the United States via England in its earliest times as people immigrated to the west. The colonists used auctions to dispose of property under the judicial process or to close out stocks of merchandise (Cassady, 1967). As areas within the east coast became settled, auctions increased. The most prevalent auction method was the English or ascending-bid system (See Types of Auctions Section).

From its earliest times, the auction has served the purpose of selling a good. Today, almost everyone who has ever connected to the internet is familiar with auctions through eBay. eBay started in 1995 as the brainchild of Pierre Omidyar. Omidyar was trying to help his girlfriend buy and sell her Pez dispensers; this Web site ran much like the stock market for people to buy and sell consumer goods (Suber, 2007). From the Pez dispenser idea, this Web site evolved to what the internet world knows as eBay – auctions are an everyday phenomena.

The following section is a compilation of previous NPS Theses on Auction Theory. Information is taken from the following Thesis authors: William N. Filip, Pei Yin Tan, and Henning Hansen Homb.

B. VOCABULARY OF AUCTIONS

Auctions come in various forms; however, the terminology of an auction remains constant. The *Bidders* are the persons competing for the good at hand. The *Bid-takers* are the persons receiving the price offers from the bidders. The *Seller* is the person who possesses the good or service at hand and who is willing to provide it for the right price. The *Buyer* is the person looking for a good or service.

C. TYPES OF AUCTIONS

1. Ascending-bid (English Auction)

This type of auction is the most common. It involves bidders raising the price until only one buyer is left. This auction can be run three ways: 1. the seller announces prices, 2. the bidders call out their prices, or 3. bids can be submitted electronically with the best current price listed (Klemperer, 2004).

2. Descending-bid (Dutch Auction)

This type of auction is exactly the opposite of the ascending-bid auction. In this scenario, the price starts out higher than any buyer is willing to pay and lowers continuously until the first bidder is willing to accept the good at the current price (Klemperer, 2004).

3. First-price Sealed Bid

This type of auction consists of each bidder submitting their bid without the knowledge of the other bidders. In this scenario, the good goes to the bidder who has submitted the highest bid and the winner pays the price they bid (Klemperer, 2004).

4. Second-price Sealed Bid

This type is very similar to the first-price sealed bid auctions. In this scenario, the winner is still the bidder who has submitted the highest bid; however, the bidder only has to pay the price of the second highest (or first excluded) bid (Klemperer, 2004).

D. KEY FEATURES

1. Forward Versus Reverse

a. Forward Auction

A Forward Auction is the most common form of auctioning and one that is most familiar. It involves a single seller of a good and multiple buyers bidding for the right to purchase that good. Usually the winner of this type of auction is the bidder who submits the highest bid.

b. Reverse Auction

A reverse auction consists of one buyer and multiple sellers vying for a specific good. In a reverse auction, the winner is the bidder with the lowest bid.

2. First-price Versus Second-price Bidding Strategies

a. First-price

In a forward auction, the winning bidder pays what he bid for the item; in a reverse auction the bidder gets paid what he bid. In the forward auction, if the bidder wins the auction that is below his private-value, then he receives a profit. In a reverse auction, the bidder who wins the auction above his reserve price receives a surplus. Bidders can use information or "signals" to determine the amount they are going to bid to maximize their profit or surplus. Bidders will under bid their true valuation in a forward auction and they will bid above their true valuation in a reverse auction.

b. Second-price

In a forward auction, the winning bidder pays an amount equal to the second highest bid. In a reverse auction, the winner is paid an amount equal to the first non-winning bid. In each case, one's bid is only used to determine if he is the winner. The amount the bidder pays or gets paid depends on the bids of others. In both types of auctions, the dominant strategy is for each bidder to submit a bid equal to their true valuation of the item.

3. Common Value Versus Independent Private-Value

a. Common Value

The value of the item is common or the same for each bidder; however, bidders have different private information about what the value actually is. For example, the value of land that supposedly has oil underground will have the same value to any buyer who plans to drill the oil. Bidders may have access to different "signals" about the amount of oil located underground, so they may have different perceptions about its common value. In this case, bidders might change their estimate if they learned of another bidder's signal.

b. Independent Private-Value

The value of the item is whatever the individual bidder values the item to be. This information is private to the bidder. This does not preclude bidders from changing their bid to gain an advantage once they find out the bids of others. An example of this would encompass a contractor bidding on a job. The contractor knows what the job will likely cost him; however, he does not know what it will cost other contractors.

4. Open Versus Sealed-bid

a. Open Auctions

An open auction consists of the bidders knowing the competitions' bids. Bids can be called out by an auctioneer, the bidders can call out their bids, or a bid can be posted electronically. The key to an open auction is that bidders know what others are bidding.

b. Sealed-bid

In a sealed-bid auction, the bidder only knows his bid. All bids are submitted somewhat simultaneously as each bidder submits one bid. In this case, the bidders must estimate what other bidders may bid to maximize their chances of winning.

E. FACTORS WHEN DECIDNG AUCTION FORMAT

Several factors need to be considered when deciding on the type of auction to be used. The objectives may differ for each seller in different auctions. According to the Revenue Equivalence Theorem (RET), the design of the auction does not matter as each type generally yields the same revenue for the seller. The following factors should be considered when designing an auction:

1. Revenue Equivalence

According to the RET, all four types of auctions yield the same revenue on average under the following assumptions:

- Bidders are risk neutral
- Independent private-values assumption applies

- Symmetric bidders (each draws from similar probability distributions)

- Payment is based only on bids

If these four criteria are met, it does not matter which design is chosen and the expected value for each auction will be generally the same. For example, the English and second-price sealed-bid auctions will yield the same revenue as the winner pays the second highest value. In the Dutch and first-priced sealed-bid auctions, the winner will attempt to outbid his competition by the slightest value to maximize his economic rent. By meeting the four criteria described above, the RET would prove to be correct. However, most auctions will fail to meet the criteria of the RET and bidders tend to act differently within each design. Klemperer raises the issue of collusion and the attractiveness to potential bidders as reason for susceptibility. An auction designer needs to understand the purpose of the auction to design it correctly.

2. Risk Tolerance Amongst Bidders

Information is a key aspect in all forms of auctions. In the open form auctions, bidders can view their competitors' bids; whereas, in sealed bid auctions, the bidder is dependant on the information he has gathered to submit a bid based on his value. The amount of information or lack of information creates uncertainty and risk.

Generally, a risk neutral bidder's behavior is not affected by an increase in risk, and, therefore, such a bidder will approach all types of auctions in the same manner. On the other hand, most individuals are risk averse and will attempt to decrease their risk and increase their certainty. A risk averse person will tend to bid more aggressively to increase the probability of winning and reduce the uncertainty. This also would decrease the surplus value received from the product if a risk-averse individual is the winning bidder. Risk averse bidders will typically generate higher values for the sellers in the Dutch and first-price sealed bid auctions compared to the English and second-price sealed bid auctions.

3. Collusion

Individual bidders would like to collude in auctions to keep prices at a minimum. In open auctions, collusion could occur through signals among bidders or through the bid itself, especially if the product is of value to the bidder. In addition, a bidder who is not cooperating with a colluder could be forced into paying a much higher price for an item than if the bidder had cooperated. In sealed-bid auctions, collusion is very rare as there is no communication between the players in the bidding process; collusion requires pre-agreement concerning the sealed bids. A seller would obviously attempt to thwart collusion, using one of the following options. First, the seller can set a reserve price (see below). Second, if the seller becomes aware that collusion is occurring, the item being auctioned can be removed and saved for another day. Third, an auctioneer could remove suspected colluders from the auction. Finally, an auctioneer could revert to unethical practices and utilize a ghost bidder to raise the price of an auction.

4. Reserve Price

For a seller to guarantee an appropriate profit, he may set a reserve price. This is a minimum price (forward auction) or maximum price (reverse auction) set at the outset to guarantee minimum revenue or maximum cost. These prices must be set carefully so they don't discourage potential bidders from bidding. For example, in a forward auction a seller could set a reserve price of $500 for an item when a bidder values that item to be $400. As a result, this potential bidder would not participate in this auction. If this reserve price scares off all potential bidders, the seller would lose his sale even though he could have potentially received his value through the auction.

Setting reserve prices could also deter collusion. If the seller sets his price to receive a profit, he will get bids assuming the price is not too high. It would not matter if colluders minimized the value or the bids; the seller would still receive some profits. Overall, setting a reserve price would reduce the incentive for bidders to cooperate.

5. Private Information

As stated previously, information is a key aspect to an auction. Information would include knowledge of the product or service, quantity available, historical sales, or competition involved. The value of an item to an individual could differ depending on how much he knows about that item. Auctioneers tend to provide information that would increase the bids to increase revenue. On the other hand, certain information may cause bidders to revise their bids downward. An auctioneer or seller must decide what and how much information to divulge to the bidder.

Information can also increase uncertainty. If a seller releases certain information that may cause a bidder to increase his value of an item, then the risk averse bidder would increase his bid to increase his probability of winning the item.

6. Number of Bidders

An increase in competition or the number of bidders usually increases the seller's revenue. In this case, it would be to the seller's benefit to increase participation in an auction. This could also serve the purpose of a reserve price. In Dutch and first-price sealed bid auctions, more bidders tend to generate higher bids for an item as increased competition (uncertainty) and risk aversion cause participants to alter their bids; whereas increased competition in an English or second-price sealed bid auction would not change the bidding strategy, as the bidder only bids his value of an item regardless of the competition (however, the highest and second highest valued bids are likely to increase with increased participation).

7. Other Factors

Auction design can be influenced by other factors. These include: entry fees to participate in an auction, time limits instilled for the auction, and a middleman representing the bidder.

Entry fees could be charged to participate in an auction. This could separate those undesirable bidders from the more serious bidders. In addition, an entry fee resembles a reserve price, as those with low valuations of an item would be excluded. One drawback to an entry fee, especially in an assignment or bonus setting, would be that individual bidders would tire of submitting bids if it becomes non-refundable and the guarantee of return dwindles.

Time limits would control the amount of information that individual bidders could collect on other bidders to determine their value of an item or a competitor's bidding strategy. Time limits would also increase uncertainty. As stated previously, a risk averse participant would bid more aggressively to decrease uncertainty. A tight time limit imposed on an assignment or bonus auction for the military would not necessarily be suitable. Military personnel are dispersed throughout the world and information on auctions and ways to submit bids may not always be available in a timely manner.

The last factor to consider is that of the middleman. A middleman could represent the bidder. To do this, the middleman must know the bidder's valuation and must definitely know the bidder's maximum bid in a forward auction and the minimum bid in a reverse auction. Also, it would be in the best interest of both the seller and the bidder for the middleman to know some information about the item up for bid. A positive aspect of the middleman includes the fact that military personnel could still participate in an auction no matter what their geographical or technological status, assuming they understand the previous issues.

F. CHAPTER SUMMARY

This chapter introduced the history of auctions. Following the history of auctions, a vocabulary of auctions was defined. Next, the four basic auction types were described. They are the English, the Dutch, the first-price sealed bid, and the second-price sealed bid auctions. Then some key features were described. The difference between forward and reverse auctions, the different bidding strategies, the difference between Common Value versus Independent Private-Value auctions, and the difference between open versus sealed bid auctions were described in this section. The chapter concluded by looking at the design factors that should be considered. These include: revenue equivalence, risk tolerance, collusion, reserve prices, private information, number of bidders, and some other factors that would need to be included for military personnel.

IV. APPLICATION OF AUCTIONS

Utilizing auctions in the Army's pilot bonus system could enable the service to provide a bonus to the commissioned officer pilot; not only the warrant officer pilot. The warrant officer pilot is the Army's expert when it comes to flying its inventory of aircraft and a bonus system is very much needed to ensure the manning levels of these experts remains optimal; however, as the Army increases by 65,000 soldiers in the upcoming years and as the Global War on Terrorism continues, the Army also needs to retain the commissioned officer pilot. Currently no bonuses are offered to these pilots and an auction format utilized for the warrant officer retentions could enable the dollars to be spread among the other worthy pilots.

Auctions provide a method where there are no standard values, as the value of a pilot in the military could not be determined for every individual. In addition, the price of labor depends on the supply and demand conditions at a specific time (Norton, 2007). For example, if the supply of pilots is low at a certain time interval, the price the military would have to pay for a pilot would be high; the Army would be willing to pay this price if the demand was high enough. On the contrary, if the supply is high for pilots, the military would need to pay a lower price for that same labor, and would be willing to pay that price even if the demand was lower. Another reason auctions would be beneficial to use is that auctions find the right price for any particular service or product; auctions could assist in finding the right bonus for Army pilots as they set the minimum price required to retain the targeted number of pilots (Norton, 2007).

There are several considerations in designing an auction for the context of aviator bonuses. Auctions can also have their drawbacks as complications could arise. These will be noted at the end of the chapter.

A. AUCTION FORMAT CONSIDERATIONS FOR ARMY AVIATOR RETENTION

After defining the several options to an auction, it is decided that a reverse auction would be utilized for the aviator bonus system. The military would be the sole bid-taker for the services provided by the aviator, and the eligible aviator would be the seller of his particular labor service, piloting an aircraft. Both open or a sealed-bid auctions with the final bonus calculated based on the winning bid or the second lowest bid could be used to determine the value of the bonus. Tan (2006) and Homb (2006) compare the four auction formats using five decision criteria: efficiency, cost effectiveness, equity, practicality and manipulability.

1. Efficiency

Efficiency in auctions is accomplished when the surpluses for the bid-taker (US Army) and the bidder (the aviator) are maximized and the “right” individual wins the auction. For example, if the military wants to provide the minimal amount of incentive pay and is apathetic about which aviator wins the auction, the surplus associated with the incentive bonus will be maximized whenever the aviator with the lowest bid wins the auction. The surplus is independent of the actual bonus paid; the actual bonus simply divides the surplus between the Army and the aviator (Tan, 2005).

As stated in the previous chapter, winners of auctions are determined differently in each auction and bidders’ strategies will likewise vary per auction type. In English and second-price sealed-bid auction, a bidder who truly bids his self valuation and wins by offering the lowest bid is considered efficient. On the contrary, if the bidder witnesses bids lower than his true valuation, he should drop out. In the Dutch and first-price sealed-bid auctions, the bidders must consider the values and strategies of the other bidders in the auction and must submit their bids based on the auction’s expected surplus and also their own expectations of winning the auction. Information on other bidders would be a tremendous benefit to any single bidder if at all possible to obtain. Auction theory does suggest, however, that the outcome of all four auction types should be essentially the same under normal circumstances, where the winning bid is achieved by the second lowest bid.

Homb (2006) points out that the dominant bidding strategy in a second-price sealed-bid auction is to bid your true value. However, to many economists' surprise, bidders frequently stray from the norm and under bid their true value in reverse auctions, because they believe they then have a better chance of winning the auction. Economists believe this stems from the lack of information available in a sealed-bid auction and also because the bidders do not truly understand the auction. With this idea, the revenue equivalence theorem fails and with it goes efficiency.

2. Cost Effectiveness

The current War on Terrorism has affected the military budget from the outset. As the war continues, more bills emerge and the cost of continuing the war grows daily. Auctions could emerge as a way to keep costs at a minimum or reroute the dollars elsewhere by their cost effectiveness. The objective of auction theory in the aviator bonus system would be to provide the aviator the minimum possible bonus to retain him. As stated in the previous chapter, the revenue equivalence theorem states that no matter which auction type is chosen, the auction's outcome should yield the same result assuming that all bidders are risk-neutral.

Homb (2006) and Tan (2006) reaffirm that the majority of people are risk averse and that the revenue equivalence theorem fails the basic tests that were described in the previous chapter. A risk averse bidder will tend to bid more aggressively in a Dutch auction and a first-price sealed-bid auction. A risk averse bidder inherently is willing to sacrifice expected surplus value to increase their chance of winning the auction; however, this actually would transfer that surplus to the employer (Army). Accordingly, as the number of bidders increases, the more aggressive these bidders become, causing the Army's surplus to grow even more. In conclusion, the military would benefit from a Dutch auction or a first-price sealed-bid auction if the studies accurately portray the bidders to be more risk averse and there are sufficient bidders to maximize the surplus to the military while minimizing the payout to the aviator or bidder.

3. Equity

In most cases, aviators at the same rank have the same the experience levels and educational qualifications. To pay one individual more than the other would be inequitable. It is a difficult task to assign an equitable bonus in auctions; however, the second-price auction formats ensure equal pay since the winners of a specific auction are paid the same bonus. On the other hand, a different pool of aviators with the same experience could yield a different bonus value in a different auction. The other auction formats do not yield the same bonus to similar aviators and the valuations can vary tremendously between individuals depending on the level of competition. If there was one auction, the second price format would be chosen. However, requirements to retain aviators differ yearly and a different auction would be needed each time; therefore, no auction format fits perfectly in the bonus context (Homb, 2006).

According to Professor William Gates (personal communication, September, 2007), the other definition of equity is equal surplus values across similar people. If one aviator will reenlist for $2,000 and the other for $25,000, and they both get paid $25,000, the first aviator receives a $23,000 profit, or surplus, while the second receives zero. It might be more “fair” to pay the first aviator $23,000 and the second aviator $45,000, giving both a profit, and surplus of $20K. There have been complaints that some service members receiving bonuses would have reenlisted for nothing, so they are essentially receiving “free” money, or pure profit. A first-price sealed-bid auction is more equitable in this sense, but still faces the sequential auction problems.

4. Practicality

The open auction formats are literally not feasible in a military setting. It would be impossible to gather all potential aviators (bidders) in one place, even virtually, to conduct the auction. It would also defeat the purpose of saving the service money as each aviator would have to be paid for their travel and accommodations in order to participate in the auction.

A much easier and manageable auction would be the sealed-bid option. As far as which type to conduct, first or second-price, that would be a matter of a simple education, which could be done through the internet. The reason for the education about an auction reflects the fact that most people are only familiar with first-price type auctions, where they submit a bid, the bid with the lowest value (reverse auction) wins the auction and the winner receives the price bid. Although, it is not inherently difficult to understand the second-price auction, it is unfamiliar territory to most observers.

Another factor that would need to be clarified is the idea of the reverse auction. Most military members understand how contracts are awarded, especially aviators, and therefore would need to realize that the lowest bid or second lowest would turn out to be the winner. This may seem obvious; however, it is important to ensure that everyone participating in the auction understands specific details of the auction. The bottom line is that dollars are involved and both sides, the military and the aviator, need to be aware of the rules. The sealed-bid auction could be accomplished through a secure internet site or a more formal memorandum sent by the individual aviator. In both cases, it is more practical to conduct a sealed-bid rather than an open-bid auction. Finally, the first-price auction would be an obvious choice to conduct as most aviators are already aware of the format; however, if the right education is performed, the second-price would be just as feasible and produce a better option to the service.

5. Manipulability

A sealed-bid auction would be the most advantageous type to avoid manipulation or collusion, as described in the previous chapter. First, the bidder (aviator) could collude more easily in an open auction as each member would be able to witness others' biddings and each person's valuation. As described above, an open auction would not be feasible anyway. Collusion in sealed-bid auctions depends in part on the number of aviators bidding. If the number of aviators bidding in an auction is large, colluding would be kept to a minimum; however, if the number is small, the chance of collusion increases. It increases even more when the bidder's know each other. In the case of aviators, the likelihood that an aviator knows the other aviators he is bidding against is a concern as most aviators progress together from their initial training and proceed with their careers through very similar pathways.

For the purpose of this thesis, collusion would be difficult even with a small number of aviators bidding due to the following reasons: the Global War on Terrorism has put aviators all over the world and it would be difficult for aviators to contact one another and receive a timely response. Furthermore, even though most aviators have followed the same career path, their military service times are not all the same, as some aviators served as prior enlisted while others became aviators directly from high school through the Army's "High School to Flight School" recruiting technique. These factors inhibit collusion and would work as a mechanism to separate the aviators that have been tracking career paths together. The other way to avoid collusive activity would be to alter the auction format and set a time limit for submitting bids. The aforementioned auction format considerations would apply.

The bid-taker in the auction could also manipulate the auction and the bidding process. In a second-price sealed-bid auction, the bid-taker could input a bid just above the lowest bid in order to grant the winner an amount close to the lowest bid. In a military style auction, it would be difficult to accomplish this in a public forum; however, it is a concern that the aviator (bidder) would consider when deciding on his bid.

The collusion dynamic is a real issue that must be factored in when deciding on an auction format. The sealed-bid format would be the most advantageous way to overcome this issue.

B. COMPLICATIONS WITH THE USE OF AUCTIONS IN DETERMING THE AVIATOR BONUS

Of all the considerations described, the equity issue would be the most difficult to overcome. Although each individual aviator submits a bid with their true valuation, theoretically, the amount offered for a bonus would need to be equal among the ranks. As stated above, this would be viable in a single auction; however, if multiple auctions were needed in sequential timeframes, the bonus offered could be different than a previous auction.

Another complication could arise if an aviator feels that his qualifications and experience overshadow others and submits a higher bid than his true valuation. Although this aviator may indeed perceive his experience correctly, he could lose the auction, not receive the bonus offered, and the Army could lose valuable experience in that particular aviator. Experience and qualifications differ immensely in the aviator arena. Aviators throughout the population would need to be educated to submit bids based solely on their true valuation.

C. CHAPTER SUMMARY

This chapter discussed five factors that must be considered to evaluate an auction for aviator bonuses in the Army: efficiency, cost-effectiveness, equity, practicality, and manipulability. It was determined that the second-price sealed-bid auction would be the best option for the Army aviator bonus system. After outlining these considerations, it was determined that there are two main complications to conducting an auction for Army aviator bonuses. The first would be equity of the bonus among the individual aviators and the second would be practicality; aviators might be tempted to submit higher bids than their true valuation. They would base their higher bid on what they perceive to be their worth. They could, in turn, lose the auction and not be offered the bonus that would resulted from the auction. The Army would lose a valuable aviator and the aviator could end his illustrious career. A complete understanding of the auction and its format could overcome these issues.

V. GAME THEORY AND STRATEGY APPROACH TO AVIATOR AUCTIONS

A. INTRODUCTION

Anyone associated with the government understands the concept of government contracts and who the winner is – the lowest bidder. These contracts are usually bid in the form of a sealed-bid. In the sealed-bid "envelope" is the price for which that particular company says it can do the job. The amount that the contractor, wrote on that sealed-bid depended on different things. First was likely the actual cost of doing the job. Second could be the amount of profit the contractor would be willing to accept. Third would possibly include an estimation of what the other contractors might bid. Fourth might be a careful calculation of the amount that would increase the contractor's chances of winning the bidding auction or contract. Considering these factors, the contractor has to decide what price to write down in his bid. If he underbids, he may increase his chances of winning the contract; however, in the end, he reduces his profit margin and might not cover all his expenses incurred in the actual contract work. If he overbids, he would potentially increase his profit margin; however, the chances of him winning the contract dwindle. The third option would be to bid the true valuation of the contract.

Dixit and Nalebuff (1991) note in their book, *Thinking Strategically*, that choosing your bid is a strategic decision in a first-price auction. Suppose costs of all potential bidders are distributed uniformly and randomly over some range involving 10 possible bidding increments, and, as a contractor, your cost is at the midpoint of that range. Five times out of ten, some rival will bid less than your actual cost in a first-price auction and you will loose the auction whether you over inflate your bid or bid your true cost. Four times out of ten, a rival will inflate their bid and you could have won the contract with an inflated or an actual cost bid, with the inflated bid earning you more profit. There is a one chance in ten that a rival submits a bid at essentially your actual cost. Therefore, an actual cost bid may win you the contract, but the profit margin is minimal, as you would just cover the costs, and the contract was barely worth having anyway. In these cases, Game Theory suggests that submitting an inflated bid is a dominant strategy. The other participants in the auction are usually thinking along these same lines anyway (Dixit and Nalebuff, 1991, p 319-320).

The above scenario could be used to describe the bidding process for an aviator when submitting his bonus value in a first-price reverse sealed-bid auction. If the aviator over inflates his bid, he may lose out. If he underbids his true value, than he is technically not being paid his worth. If he bids his true value, he maximizes his chances of winning the auction, but doesn't receive any surplus value.

This chapter will encompass a two-person reverse auction situation for both a first-price and a second-price auction scenario. Using a pure Game Theory approach and other mathematical models, the analysis will determine the bid an aviator should submit.

B. GAME THEORY

> Conflict has been a central theme throughout human history and literature. It arises whenever two or more individuals, with different values, compete to try to control the course of events. *Game Theory* uses mathematical tools to study situations involving both conflict and cooperation. Its study was greatly stimulated by the publication in 1944 of the monumental *Theory of Games and Economic Behavior* by John von Neumann and Oskar Morgenstern (COMAP, 1996, p. 561).

A game consists of players and strategies that lead to outcomes. In Game Theory, the players consist of individuals, organizations, and sometimes even countries. Strategies are the options or courses of action between which the players must decide. Once the players decide on strategies, an outcome occurs which determines the consequences of their decision. Game Theory assumes that individuals prefer different outcomes. "Game Theory analyzes the

rational choice of strategies – that is, how players select strategies to obtain preferred outcomes" (COMAP, 1996, p. 561).

As stated previously, Game Theory analyzes situations in which there are at least two players rather than an individual making a decision. An outcome depends on the decisions of the other players. Sometimes these decisions may be cooperative; however, most of the time the decisions are uncooperative, such as two teams competing on the playing field. In these situations, one team's gain is another team's loss. In economics however, joint gains could be realized through minimal cooperation.

There are two basic conflict games in Game Theory: total-conflict and partial-conflict. Total-conflict consists of one team winning while the other loses, which is known as zero-sum. The best example of this occurs in a football game where, in most cases, cooperation with the other team never occurs. When the game finally ends, there clearly is a winner and a loser. A partial-conflict instance occurs when the players can actually benefit from cooperation, but, nonetheless, may have an even stronger incentive not to cooperate. An example of a partial conflict game is that of the Prisoner's Dilemma, one of the most famous Game Theory scenarios, which will be described in section E. This thesis will encompass both approaches in its design.

C. GAME THEORY ASSUMPTIONS

The following assumptions are made in order to develop the matrices required to understand the outcomes of the partial conflict game and the zero sum game.

1. The bonus amount is congressionally dictated to be a maximum of $25,000 a year.

2. The two players bidding for the bonus differ in their beliefs of their true value. The first aviator considers herself average and decides that her potential bids include the following options: Underbid - $2,000; True Value - $9,000; and Overbid - $16,000. The second aviator considers himself to be a superior aviator

based on his experience and qualifications. His bids consist of the following: Underbid - $6,000; True Value - $15,000; and Overbid - $25,000.

3. The values for the game are arbitrary and based on the author's personal experience with aviators, histories of bonuses given by the Army and other services, and are cardinal values (the value of the bid is the actual number/1000).

4. This chapter will be analyzed using the following matrix of the each bidder's values. See Figure 5.0 below.

		Colin					
		Under		TRUE		Over	
Rose	Under	2	6	2	15	2	25
	TRUE	9	6	9	15	9	25
	Over	16	6	16	15	16	25

Figure 5.0 Cardinal Value Matrix

D. TOTAL CONFLICT – ZERO SUM

A zero-sum game is one in which the payoff to one player is the negative of the corresponding payoff to the other player, so the sum of the two payoffs is always zero. Basically, one player benefits at the other's expense. Auction theory does not allow a zero-sum to exist. For example, a way to possibly develop a zero-sum matrix, such as in Figure 5.1, would be to run a first-price reverse auction. The lowest bid wins, and the loser of the game does not receive a bonus and also has to pay the winner the amount won in the auction. This does not provide any value to an auction in any of its uses for bonus amounts for jobs or skills, but serves as an introduction to a standard Game Theory concept. This game consists of the players bidding their values based off of Figure 5.0. An example of how the values are achieved in the matrix is described as in the (Over, Over) part of the matrix. Rose overbids the value of $16,000 while Colin overbids his value of $25,000. In the reverse auction, the lower bid wins; therefore, Rose wins with the bid of $16,000. Because Colin overbid, he loses the reverse auction and has to pay out $16,000 to Rose according to the rules of zero-sum games.

		Colin					
		Under		TRUE		Over	
Rose	Under	2	-2	2	-2	2	-2
	TRUE	-6	6	9	-9	9	-9
	Over	-6	6	-15	15	16	-16

Figure 5.1 Zero-Sum

It would not be feasible to study a zero-sum game for the purposes of aviation bonuses with respect to auction theory. However, a way to utilize Game Theory, and determine bidding strategies would be look at a partial conflict scenario by utilizing payoff matrices in both a first-price and a second-price reverse auction. An example of a partial conflict game is described below in the partial conflict scenario with the Prisoner's Dilemma.

E. PARTIAL CONFLICT

> Two-person partial-conflict games are variable-sum games in which the sum of payoffs in each of the four payoff strategy spaces varies, and does not necessarily sum to zero as in zero-sum games. Invariably, in partial-conflict games there are some reciprocal gains both players can realize through cooperation, but this is often improbable in the absence of either good communication or trust. When trust or communication is poor, the condition is set for a noncooperative game, whereby no binding agreement is possible or enforceable. Even in instances allowing communication, there is no assurance that a player can trust another player to choose the particular strategy that he promised to select. Self-interests may actually result in choices that yield lower payoffs than could have been achieved through cooperation (Ecklund, 2005, p. 25-26).

1. Prisoner's Dilemma

One of the most recognizable games or situations in Game Theory is the Prisoner's Dilemma, which originated from Princeton mathematician Albert W.

Tucker in 1950. The Prisoner's Dilemma is as follows. Two individuals are accused of a crime and are held separate from each other. Each has two choices: the first is to maintain his innocence and the second is to sign a confession also accusing the other individual of the crime. Each knows that if neither of them talks, the case against them would be weak and the authorities will convict and punish them for lesser charges, warranting only one year in prison. If both confess, each will get ten years in prison. If only one confesses and testifies against the other, the uncooperative prisoner will receive fifty years, while the cooperative prisoner will get parole. See the matrix below, Figure 5.1, for an illustration of the "payoffs" for each player and their respective decision, where the numbers within the matrix are the number of years in prison. A smaller number is preferred in this scenario.

		Colin	
		Confess	Don't Confess
Rose	Confess	10 , 10	0 , 50
	Don't Confess	50 , 0	1 , 1

Figure 5.2 Prisoner's Dilemma

A rational acting player would choose his dominant strategy of "Confess" in order to maximize his payoff. "Confess" is a dominant strategy because it provides a better payoff (shorter prison time) for both possible decisions by the other player. This would result in both prisoners going to jail for ten years (10 , 10). This is the game's non-Pareto optimal Nash equilibrium. For both prisoners "Confess" dominates "Don't Confess," even though the mutual-Confess outcome (10 , 10) is worse for both prisoners when compared to the mutual-Don't Confess outcome (1 , 1).

Dominant strategies in games of noncooperation and simultaneous moves will not always guarantee the best payoff. If either prisoner decided to depart from his dominant strategy to Don't Confess, the result for that prisoner would be forty additional years in prison (0 , 50) or (50 , 0), while the player that does confess would get parole. This choice is clearly not rational, and deters both prisoners from departing from the Nash equilibrium (10, 10). Even if both prisoners had discussed the mutual benefits of not confessing before their capture, the outcome is still unstable because the incentive of zero time in prison is still present and available. If Rose believed that Colin would hold up his end of the bargain by not confessing, Rose's incentive is to confess to obtain the more desirable payoff of being set free. Each prisoner would be enticed to go back on his word and pursue a strategy of Confess (Ecklund, 2005). Thus, this leaves us with the Prisoner's Dilemma.

2. Partial Conflict Game

Based on the above assumptions, a game develops with a payoff matrix as shown in Figure 5.3 and 5.4. This game consists of the players bidding their values and a winner is determined by a first-price or a second-price reverse auction. The winning bid is then compared to the individual's true value and a respective payoff is found to determine the payoff matrix. The first payoff matrix will be that of the second-price reverse auction in Figure 5.3.

		Colin					
		Under		TRUE		Over	
Rose	Under	-3	0	6	0	16	0
	TRUE	0	-9	6	0	16	0
	Over	0	0	0	1	16	0

Figure 5.3 Second-Price Reverse Auction Payoff Matrix

The values in the above payoff matrix are determined by the following steps. First, it was determined which player won the auction within the matrix using the cardinal value matrix from above in Figure 5.0. For example, in the case where both players underbid their true values, Rose would win the auction because she submitted the lowest bid of $2,000. The next step is to determine the winning bonus amount of the auction. In the case of the second-price auction, the value of this auction bonus is $6,000, the excluded bid submitted by Colin. To determine the value within the payoff matrix, the value won is then compared to her true value of the bonus she believes she needs to receive for her to stay in the service. Since her true value is $9,000, her net value is actually -$3,000; she has accepted a bonus $3,000 below her true value. The rest of the matrix was determined the same way.

As a result of the expected payoffs from the above scenario, it is determined that both Rose and Colin should bid their true values. For Rose, she could hurt herself by underbidding if Colin underbids and she receives a positive net value in two out of the three scenarios in which she bids her true value, compared to only one out of three when she overbids. She cannot do any better by overbidding, no matter what Colin bids. For Colin, his only positive net value payoff occurs when he bids his true value and when Rose overbids. He receives $1,000 more than his true value of $15,000. He can hurt himself by underbidding and lose a possible net value gain by overbidding. By underbidding or overbidding, Colin and Rose can do no better than bidding their true value, and possibly do worse.

In a second-price reverse auction, it is a dominant strategy for both players to bid their true values if they have no prior signals or information on the other bidder or bidders. This would most likely be the case in the aviator bonus scenario as all the aviators would be spread around the world and collusion would be very difficult to coordinate (or “arrange”) amongst them.

The next scenario is similar to the one outlined above; however, the first-price reverse auction scenario will be modeled. In this case, everything remains the same as the second-price auction, but the bonus amount awarded is the lowest bid value. See Figure 5.4 for the payoff matrix in this scenario.

		Colin					
		Under		TRUE		Over	
Rose	Under	-7	0	-7	0	-7	0
	TRUE	0	-9	0	0	0	0
	Over	0	-9	0	0	7	0

Figure 5.4 First-Price Reverse Auction Payoff Matrix

The values in the above payoff matrix were determined in the same manner as the second-price; however, the bonus amount awarded was the winning bid, which is then compared to the each player's true value.

In the first-price scenario, Rose has a dominant strategy to overbid her value. In this case, she wins the auction and the amount paid is $15,000. Based off of her values, she receives a net value gain of $7,000. She definitely hurts herself by underbidding in the first-price reverse auction. She does not necessarily hurt herself by bidding her true value, but she foregoes any chance to gain a net value; she only receives a positive net value if she overbids. For Colin, it does not matter whether he bids his true value or overbids; he does not receive any net value. He does receive a loss in his net value by underbidding even though he may win the auction when Rose bids either true value or overbids.

For bidders to bid their true value, the second-price auction is the auction design that encourages that behavior. In the first-price auction, bids determine the probabilities of winning and the surplus awarded. Most participants are used to first-price auctions and understand them. To understand the process of the first-price bid, Decision Theory can be explored to show the relationship between the bid and the chance of winning the auction.

F. DECISION THEORY

1. Introduction

Decision Theory is a tool developed to assist people in choosing among different alternatives in complex situations. For an aviator, the alternatives are whether to underbid, overbid, or go with his true value. Most of the time, options are clearly defined and the consequences can be predictable; however, there is uncertainty in the exact outcome of the event. Information may be available for the likelihood of different outcomes, but uncertainty still exists (Straffin, 1993). The following is a simple example of Decision Theory.

> It's a warm, humid morning and you are about to leave your apartment to walk down to the campus that is six blocks away. You're worried that it might rain, so you consider taking your raincoat. Although your raincoat is great at protecting you from downpours and keeping you nice and dry, it's rather bulky and ugly and you'd prefer not to take it along if you don't really need it. You have two possible actions: take the raincoat with you or leave your raincoat at home. There is an unknown "state of nature": It may or may not rain. There are four possible outcomes depending on your action and state of nature:
>
> A: Take raincoat, it rains
>
> B: Take raincoat, it doesn't rain
>
> C: Leave raincoat, it rains
>
> D: Leave raincoat, it doesn't rain
>
> You will obviously be happier with some outcomes than with others. The worst possibility is that you decide to leave the raincoat in your apartment and it pours as you walk to campus, drenching you to the skin, soaking your clothes, and perhaps ruining your books. The happiest eventuality occurs when you leave your raincoat behind and no rain comes down. Then you are both dry and free of the burden of lugging the coat. The other two outcomes (when you take the raincoat) are somewhat in between; once you've gone to

> the bother of wearing the coat, you'd probably have a happier sense of vindication if it did rain than if it didn't (Straffin, 1993, p 539)

2. Applying Decision Theory to the Auction

Decision analysis assists in dealing with complicated situations. The aviator must decide whether to underbid and increase his chances of winning the auction but receiving less money than what he feels he deserves; or he must decide to overbid and decrease his chances of winning the auction, realizing, however, if he does win his surplus is maximized in the bonus he receives; or he must decide to bid his true value and hope that others do the same. The aviator must balance between the conflicting demands of maximizing expectation (the bonus amount) and minimizing the risk (winning or losing the auction). "[O]ne guiding principle is always present: Determine as best you can the probabilities … for the various outcomes as well as the value, or utility, of these outcomes" (Straffin, 1993, p.540). Once this determination has been made, the expected value of the scenario can then be computed. An expected value is defined as: $EV = ap + b(1-p)$, where payoff a occurs with a probability of p, payoff b occurs with a probability of $(1-p)$. Applying the Dixit and Nalebuff example introduced in the beginning of this chapter, to the aviator bonus auction scenario, five times out of ten (.5) some rival will bid less than the actual required bonus, four times out of ten (.4), a rival will bid over the required bonus, and one chance in ten a rival submits a bid at approximately the required bonus or true value.

To apply this expected value model to the decisions facing Rose and Colin, assume that Rose and Colin don't know each other's true required bonus, but know that they follow a uniform distribution. The values of the bids, for a risk neutral bidder, range from $0, reflecting that an aviator will continue to remain in service at no additional cost, to $25,000, for aviators that would only be willing to stay in the service if paid this amount. The probability associated with each bid is the same, thus the uniform distribution. The following graph shows the uniform distribution, Figure 5.5,

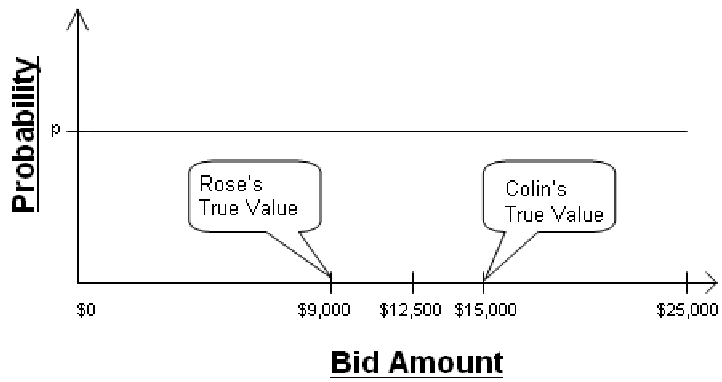

Figure 5.5 Uniform Distribution of Bids vs. Probabilities

In the above scenario, each player knows his or her own true value. However, they do not know the other's true value. In a first-price auction, it would make sense for either bidder to bid below their true value. If they do, their chances of winning the auction do increase; however, they would win the first-price reverse auction and receive a negative surplus. Decision Theory comes into play with this scenario in describing how each bidder determines his or her bid. As I just stated, neither person would bid below his or her true value, but the question is how much to bid above that value and what is the associated chance of winning the auction. In the uniform distribution ranging from 0 to 25 in thousands, the $P(bidder(wins)) = \frac{25-B}{25}$ and $Surplus(bidder) = B - (true\_value)$. Rose's true value remains $9,000. If she bids her true value and bids must be in $1000 increments, she has a $\frac{16}{25}$ chance at winning the auction. For every dollar she increases her bid, her chance of winning decreases; however, if she wins, her surplus increases. For example, Rose's chance of winning the auction at a bid of $12,000 decreases to $\frac{13}{25}$, but she receives a surplus of $4,000 if she wins the auction. The same scenario arises with Colin and his bids. At Colin's true value of $15,000, he has a $\frac{10}{25}$ chance of winning the auction. As Colin increases his bid he also decreases his chances of winning a first-price auction; however, he also increases his surplus should he win.

The next step to Decision Theory, is to determine the value that balances the surplus for each bidder with the probability of winning the auction. This is done in the following manner. For Colin, his true value remains at $15,000. He bids (B), therefore: $Surplus(Colin) = B - 15$. The probability of winning is $P(Colin(wins)) = \frac{25 - B}{25}$. The expected surplus is calculated by multiplying $Surplus(Colin) * P(Colin(wins))$. The value can be calculated by the following: $\frac{-B^2 + 40B + 375}{25}$. The maximum expected surplus is found by taking the first derivative of this equation and then setting it equal to zero. After the derivative is taken, a simple equation determines the value that Colin should bid. For Colin, his equation is $2B = 40$ or $B = 20$. Therefore, Colin should bid $20,000. His chances of winning are $\frac{5}{25}$ or $\frac{1}{5}$. Should he win this auction, his surplus would be $5,000.

Rose's situation is determined in exactly the same manner; however, her true value is lower at $9,000. She bids (B), therefore: $Surplus(Rose) = B - 9$. The probability of winning is $P(Rose(wins)) = \frac{25 - B}{25}$. Her expected surplus is calculated by multiplying $Surplus(Rose) * P(Rose(wins))$. The value can be calculated by the following: $\frac{-B^2 + 34B + 225}{25}$. Her maximum expected surplus is calculated by taking the first derivative of this equation and then setting it equal to zero. After the derivative is taken, a simple equation determines the value that Rose should bid. For Rose, her equation is $2B = 34$ or $B = 17$. Therefore, Rose should bid $17,000. Her chances of winning are $\frac{8}{25}$. Should Rose win this auction, her surplus would be $8,000.

As illustrated by the above calculations, the following information could be extrapolated from using Decision Theory with an expected value model: knowing what the true value of the auction, a bidder can determine the probability of winning and the expected payoff or surplus for each possible bid. Furthermore in a first-price reverse auction, no bidder would bid less than his or her true value as it would only result in a net loss of revenue. In general, risk neutral bidders would determine the bid that maximizes expected utility. In this case, Rose and Colin would bid 17,000 and 20,000, respectively. Rose would win the auction and receive a 17,000 bonus. Notice that in this case, the first price auction results in a higher bonus payment than the truth-revealing second price auction (Rose wins and receives 15,000). Clearly, the relative outcomes depend on the number and characteristics of the bidders involved. The revenue equivalence theorem, described previously, indicates that the two auctions outcomes will coincide on average with a sufficient number of risk neutral bidders. If bidders are risk averse, the first price auction will reduce the cost of retention bonuses.

In a first price auction, how much might a bidder strategize and what happens if communication could occur amongst bidders? The following section on Strategic Moves provides insight on how bidders may communicate.

G. STRATEGIC MOVES

“Games” in real life are played in one of two ways: with communication or without communication between players. Everyday people utilize strategic moves without even knowing it. For example, a strategic move that everyone plays in the military is that of the assignment process. When a member of the military is conversing with his career manager on assignments, he is trying to influence the outcome of duty station by using strategic moves, such as commitments, threats, and promises. Both participants in the process (military member and Branch Manager) have their own ideas about what assignment should be given. The military member considers issues like location, family and career; the branch manager considers the service’s needs. For each person to achieve his goal, one must sometimes utilize “strategic moves”. For example, a branch manager may promise the assignment that the military member wants if the member is able to go to another assignment at first to fill a requirement for the branch manager. Also, the military member may threaten resignation if he does not get his choice assignment. Sometimes both threats and promises are needed.

1. Strategic Moves Description

Ecklund (2005, pp. 31-33) provides a synopsis of strategic moves written by Straffin (1996) with the following text.

> Straffin (1996) describes most situations where players do not choose strategies simultaneously or choose strategies without communication. Strategic moves in zero-sum games with no saddlepoint and consecutive moves gives [sic] the player who moves last the distinct advantage and benefits from knowing the other player's choice before moving himself. In variable-sum games there are instances when it is beneficial to make the first move.
>
> If not possible for one player to move first in a game, communicating a commitment to a move could achieve the same effect. The difficulty arises in trying to make a commitment convincing to the other player, especially when the other player would like to commit and when conflicting commitments are mutually damaging. In cases where conflicting commitments are mutually damaging, one can make a commitment, and then sever communications, thereby forcing the other player to either give in or risk receiving a less preferred outcome (Straffin 1996, 85-86).
>
> In situations where commitments would not affect the game, one may be able to apply an effective threat. A threat in the context of game theory must have the following properties: (1) "Player 1" agrees to take a certain action contingent on a previous action by "Player 2;" (2) Player 1's action will be harmful to Player 2; and (3) Player 1's action will also harm Player 1. Credibility is the crux of the successful use of threats, and is difficult to achieve since the obligation is to a self-harmful action (Straffin 1996, 86-88).
>
> In instances where threats are not credible, a promise may be appropriate, and has the following properties: (1) Player 1 agrees to take a certain action contingent on a previous action by Player 2; (2) Player 1's action will be beneficial to Player 2; and (3) Player 1's action will harm Player 1. Once again, the issue for

effectively applying this strategic move is credibility, especially convincing one's opponent of a commitment to take a self-harmful action. In cases where threats and promises are not sufficient, a combination of both a threat and a promise might be sufficient to change the outcome if they are both credible. In other instances, no combination of commitments, threats, or promises can change a game (Straffin 1996, 86-88).

2. Strategic Moves Model

Thus far in the thesis, the aviators have submitted bids simultaneously and without communication. In real life, it may not work like this, especially in the aviator field. Aviators are a very close knit group and often keep in touch with one another, especially when new items of interest arise with respect to their aircraft. Another item of interest might be the amount of a bonus; aviators would most likely communicate their intentions and thoughts as much as possible prior to submitting a bid. In this section, each aviator's choices can encompass a first move commitment, or a threat or promise to another aviator. In this model, I assume that the true values for Rose and Colin do not change and that neither would bid below their true value. In this scenario, I provide the same payoff matrix as the first-price sealed-bid auction; however, the underbid values are no longer considered. See Figure 5.6 below for the payoff matrix and a spreadsheet on the outcome of a strategic move scenario.

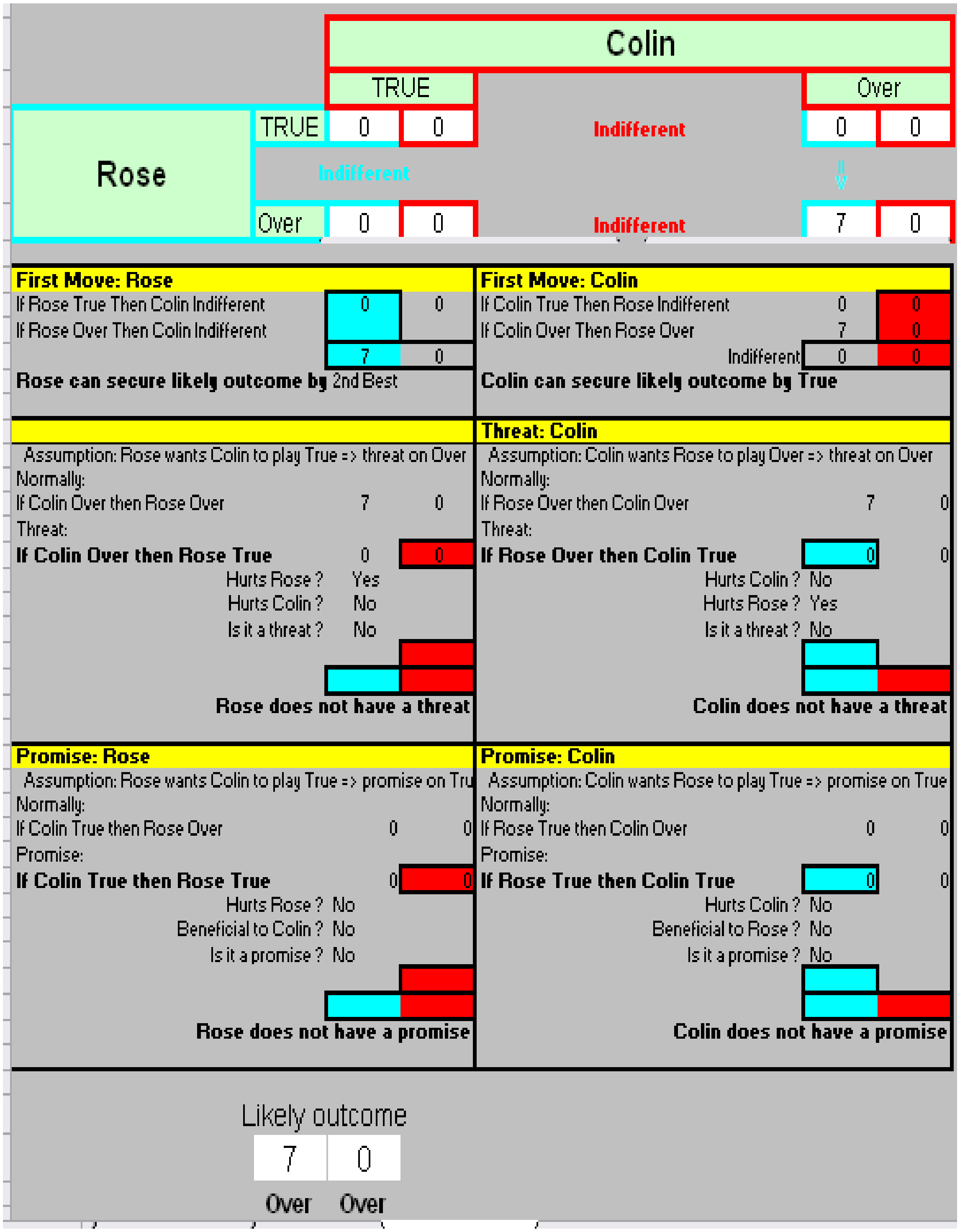

Figure 5.6 Strategic Moves in a First-Price Auction

In this strategic move first-price sealed-bid reverse auction scenario, the likely outcome would be for each bidder to overbid their true value. Colin does not receive any surplus no matter what he bids in the first-price auction. Rose receives a $7,000 surplus if she can convince Colin to use his overbid value in the auction while she also overbids. See the spreadsheet for the scenarios that represent the first move, threat, and promises. Threats would not even be considered because the more one threatens to lower his or her bid to hurt the other bidder, then the better chance of decreasing one's surplus or even underbidding one's true value. The bottom line in a strategic move scenario is that if bidders are able to communicate with each other, they will undoubtedly try to convince the other to overbid his or her true value in order to maximize surplus.

H. CONCLUSION

In this chapter, Game Theory and different strategies (Decision Theory and Strategic moves) were studied to determine how bidders could determine the value to bid in a reverse auction. Each mathematical scenario provides a bidder a more educated way to submit a bid if auctions are used to set aviator bonuses in the future. The auction comes down to two choices: First-price or Second-price. The Revenue Equivalence Theorem states that both auctions would result in the same bonus cost, because surplus maximizing risk neutral bidders in a first-price auction will overstate and overbid their true value. If bidders are risk averse, it will reduce the tendency toward overbidding, but overbidding becomes more pronounced if bidders can communicate.

The first section of the chapter used Game Theory to show that bidding one's true value is the dominant strategy for each bidder in a second-price reverse auction. This is beneficial to everyone involved: it relays the true market value to the seller, and the bidder receives a bonus that exceeds the value that he or she deems appropriate. The services should be able to determine the appropriate bonus amount utilizing the second-price format as each bidder would bid his or her true value. With this auction format, the bidding strategy is clear, once understood among the bidders: always bid one's true value; there is no information to gather, except to know what the true value is to remain in the service, and no reason to communicate threats or promises.. On the contrary, a first-price auction would entail a more difficult bidding strategy, involving a tradeoff between risk and return, and the interactions between these for risk averse bidders. There is also more potential for gaming throughout the process. Their would be significant wasted effort among bidders trying to determine others' true values and strategically communicating threats and promises regarding their own bids. The seller would never learn the true market value of the aviators at a given moment. When the player overbids, the service loses out on surplus, and when the player underbids, the bidder is losing out on his surplus. A true value bid will determine the market value of any given player at the time of the auction.

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

At the outset of writing this thesis, I questioned whether Army Aviation would be able to retain its aviators in the midst of the Global War on Terrorism while the airlines are starting to replace their baby boomer pilots. I was mostly concerned with the commissioned officers in the aviator pool, as these aviators were not currently offered any bonus; only the warrant officer branch of aviators is offered a bonus. Throughout the months of writing this thesis, the Army started to hint that there may be bonuses available to commissioned officers in every branch of the Army and that the Aviation bonus would be a $35,000. As of 13 September, 2007, the commissioned Aviator is now being offered an incentive to stay in the Army. The incentives available are as follows for the year group officer 1999 through 2004:

1. Cash Bonus - $35,000 for the officer to extend 36 months past their initial obligation, or
2. Graduate School – Priority of school funding will go to year groups 2003 and 2004, or
3. Military School – Priority of schooling will go year groups 2003 and 2004 for Ranger School or the Defense Language Institute although other schools are available, or
4. Branch/Specialty of choice, or
5. Post of Choice

Although my year group, 1997, does not fall into this scenario, I am hopeful that the Army finally recognizes the retention issues that most officers have been forecasting for the future.

In an informal survey of Aviation officers in the year groups described above, the amount of money bonus appears to make the officers on the fence think twice about getting out or staying in. The three officers I have queried say that their decision to get out has already been made; although they were intrigued by the bonus. Current and expected future deployments have taken their toll, and they are more than willing to attempt their luck at finding a job for an airline or the U.S. Customs. For those officers who have already decided to stay, the $35,000 bonus serves as extra money, or a pure surplus. For those on the fence of whether to get out or stay in, the bonus is a great incentive and should provide the impetus for that officer to stay in the Army.

In this thesis, I have described the bonus and incentive program prior to 13 September 2007 and its past history. I then continued the thesis by describing Auction Theory and ways that it could be used for aviator bonuses, including some of the drawbacks arising out of the use of Auction Theory. I completed my thesis with a mathematical description using various strategies of how one might bid in a reverse first-price or second-price sealed-bid auction. I have concluded that the services should utilize a second-price auction format to increase the probability that the bidders do, in fact, bid their true values. They may or may not win the auction as the outright bidder; however, winning bidders would receive a bonus that is comparable to the market value of a pilot.

To determine the proper bonus for the current market, a second-priced, sealed-bid auction is proposed. This type of auction would forecast the current market at the time of the auction. Competition should constrain the bonus offered, yet, those aviators that believe their value is lower than others would not necessarily be punished by submitting a lower bid because the winning bonus amount would equal the first excluded bid for all aviators. Different times call for different incentives. One way to determine an incentive that is responsive to changing market conditions is the second-price, sealed-bid reverse auction.

B. RECOMMENDATIONS FOR FURTHER STUDY

Further study could determine how the Army decided on the value of $35,000 for three years and whether the incentive is working. Other services have offered up to $25,000 a year for an incentive and the Army still lags behind. Just the fact that commissioned officers are now being considered for an aviation incentive is a small victory and a smart way to assist in retention. Prior to the recent release of this current incentive, dated 13 September 2007, only warrant officer aviators were offered a bonus.

Another area of research could involve an actual economics experiment on auctions applied to this particular problem. Upon completing this economics experiment, the data could be used to simulate a reverse auction for aviation officers two years prior to completing their commitment. Data on these specific aviators could be gathered through Human Resources Command and possibly a survey. From my experience, an officer has a good idea about whether he is staying in the service or resigning at the two year prior date. Within their last year of service, individuals are concerned about their exit from the service and focused on what they can do to transition into the civilian sector.

The bottom line for an auction is to determine who captures the surplus. In some cases more of the surplus is transferred to the service member while in others more is captured by the service. The goal is to help the services accomplish their retention goals while recapturing more of the surplus. Further research in auctions should be considered to accomplish this objective. One possibility is the Sequential Self-Selection Auction Mechanism (S^3AM) first suggested by Filip (2006) and simulated by Bock (2007).

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