DETERMING END OF LIFE POLICY FOR AIR FORCE EXPENDED SMALL ARM CARTRIDGE CASES

Graduate Research Paper

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Abstract

The purpose of this research was to explore the creation of an Air Force reverse logistics network to process Expended Small Arms Cartridge Casings (ESACC) after recent changes made by the Defense Logistics Agency ESACC Policy. Specifically, this paper explored ESACC market price, Air Force ESACC generation, use of automated equipment to process ESACCs, and Department of Defense Less than Truck Load transportation costs to create a revenue generating reverse logistics network for the Air Force. The research explored multiple models utilizing the Single Source Capacitated Facility Location Problem and how the solutions generated by those models can be used by the Air Force. This research highlighted that the Air Force needs to create a reverse logistics system to manage ESACCs or risk spending more to recycle ESACCs than what they are worth.

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I. Introduction

Background

For the last several decades the DoD has handled small arms expended brass with a closed-minded approach and ignored technological innovations. Current DoD operations lack efficiency and transparency, leading to the possibility that it may cost more to recycle brass scrap than the proceeds it generates. Previously, the DoD would hand over scrap brass to the Defense Logistics Agency (DLA) as Expended Small Arms Cartridge Casings (ESACCs) which would then be mutilated and sold. The money would then be sent back to the Qualified Recycling Program (QRP) for distribution to the installations as Special Morale and Welfare (SMW) funds. In November of 2017, DLA announced that it would stop reimbursing QRPs for the value of their ESACCs and scrap brass. Instead, DLA would process ESACCs and scrap brass received from QRPs with the requirement that services still certify the rounds as expended and pay for shipping to DLA. DLA would then sell the brass and retain all the proceeds from the sale (Defense Logistics Agency, 2017). Proceeds from the sale of ESACCs and scrap brass provide a significant source of income to most base recycling yards and boosts SMW funds. DLA's decision to stop reimbursement in the brass market caused the military services to start looking into alternative ways to re-establish the revenue stream that had been eliminated.

The majority of military bases follow similar operating procedures. Brass is expended at a local firing range and the spent cartridge casings are then certified empty by hand. At a minimum, the certifier verifies that the primer has been struck and the projectile is absent, which will qualify the brass as scrap brass. For the brass to qualify as ESACCs, it must undergo an additional 100% independent inspection so that it can be sold to onto the civilian market (Under Secretary of Defense, 2011). This is a laborious task when the 605 million small arm rounds that are expended every year are taken into account. Assuming a highly motivated Airman can hand certify 2,000 rounds an hour, at the cost of $22.78 - $28.17 an hour, then the DoD spends around $6.8 million dollars every year in direct labor costs. The total regular military compensation for a single E-2 with 2 years of experience is $45,563 annually while a married E-4 with 2 dependents and 4 years of experience is $56,336 (RMC Calculator, 2019). Direct labor costs would then easily eat up half of the estimated $13 million DoD scrap brass is worth at market price. The recycling, transportation, and overhead costs, in addition to the 14% processing fee charged by DLA also need to be taken into account. Due to lack of oversight and accountability, it is impossible to determine if the DoD is coming out ahead in the recycling process.

DLA's decision left the services with three options. The first one would be to send all ESACCs to DLA and not receive any proceeds from the sale. This decision would mean the services bear the brunt of labor costs and transportation costs to DLA and receive no reimbursement for them. This choice is not popular with the services. Alternatively, the military could pursue establishing a deformer at every base that would demilitarize the ESACCs by crushing, shredding or heating. This renders ESACCs useless in every way except to be sold as scrap brass. Due to conflicting and often confusing DLA and DoD guidance, this is already being pursued by many military bases. This is expensive for a multitude of reasons, including the initial capital cost of purchasing a deformer, the manpower and input costs of running the deformer, and the costs associated of rescreening the brass before it is deformed. Many deformers are rated to contain an accidental detonation of up to a .50 caliber round, however this does not mean that they will continue to operate afterwards. Most QRPs will do their best to ensure that all ESACCs brought to them are expended, however live rounds occasionally get through. QRPs will often have an employee rescreen the brass prior to it being deformed which adds to the overall cost of processing ESACCs. These constraints inhibit the cost effectiveness of recycling ESACCs in this manner.

The last option that the military could pursue is two-fold. Part one would consist of a waiver, signed by the Under Secretary of Defense to allow services to conduct intact ESACC sales in the continental United States. Currently, only DLA is allowed to conduct intact ESACC sales but according to the Ikes Skelton National Defense Authorization Act for Fiscal Year 2011, the services are required by law to make available a certain number of ESACCs for commercial sale (Under Secretary of Defense, 2011). For this paper, the author will assume the waiver is approved. Upon approval, the second step would be to conduct two 100% independent inspections of ESACCs before the intact ESACCs would be allowed for resale. The first inspection is already being conducted by the individuals expending the small arms at the range, also known as the point of expenditure. The second inspection, and the focus of this paper, would be to utilize technology funded by a Small Business Innovation Research (SBIR) to provide the second 100% inspection (ATACS Cybernet, 2019).

Automation Equipment

Cybernet System Corporation received a SBIR investment to build an Automated Tactical Ammunition Classification System (ATACS) which has a sub variant called the Spent Brass Sorter (SBS). The SBS is capable of sorting 10,000 rounds an hour with a 100% certainty that the projectile has been fired and a 99% certainty that the primer has been stuck by utilizing high imagery photography (ATACS Cybernet, 2019). (It should be noted that the website is currently outdated and states the SBS can only process 5,000 rounds per hour. The author has correspondence from Cybernet that the SBS has been improved upon in recent years and can handle more than 10,000 rounds an hour. It is unknown when the website will be updated.) The SBS then proceeds to sort the brass by caliber and can also sort by metal casing type. This system has been approved by the Department of Defense Explosive Safety Board as a means to accomplish the second 100% independent inspection and currently operates with the United States Army as the Army Peculiar Equipment 1412 (APE1412) (APEMS Catalog, 2019).

The United States Air Force and the DoD could leverage this technology to fulfill the legal requirement of the Ikes Skelton NDAA of Fiscal Year 2011 and provide a cost-effective solution for selling intact ESACCs on the open market. The Air Force could purchase a number of SBSs to place in optimal locations and leverage DoD less than truck load (LTL) rates to move intact ESACCs to hub locations that have SBSs. These hubs would conduct the second inspection and prepare ESACCs for resale onto the civilian market.

The first pilot study was conducted by Lt Col Luke Stover and Capt James Eimers. They pitched their proposal for the Air Force to adopt SBSs for operations at the inaugural 2018 Spark Tank Competition under the program title “Brass to Bucks”. The approved funding led to the purchase of a SBS to be installed at Lackland AFB in November of 2019.

Problem Statement

With DLA deciding to not reimburse the proceeds of ESACCs to the military, the Air Force has to determine if it should give ESACCs to DLA or if it is cost effective to leverage current technology and shipping capabilities to create a reverse logistics network to transport, consolidate, and resell ESACCs to potential buyers. To answer this overarching question, five areas will need to be explored. The first is the market price of ESACCs and the difference in price when processing ESACCs as scrap brass, selling ESACCs to ammunition remanufacturers, and selling ESACCs directly to civilian reloaders. Second, determining how many ESACCs does the Air Force generate, and from what locations, will help assess the market price of ESACCs. Third, the capital cost of an SBS will need to be explored to determine if it is cost-effective to purchase these machines, and the question of how many should the Air Force buy must be answered. Fourth, in conjunction with the number of SBSs to purchase, the Air Force needs to find the optimal location for the SBSs to reduce shipping costs and decide if the machines should be consolidated at one location or decentralized. Lastly, shipping costs from bases that generate ESACCs to facilities with SBSs will need to be determined to find the optimal locations that minimize shipping costs and the capital investment costs.

These questions will be answered through the creation of a facility network utilizing SBSs that examine the effects of shipping rates, market price of ESACCs, and the capital costs of SBS machines to determine an optimal solution that generates the most profit. Every Air Force bases’ expenditures were pulled and a three year average of the amount of ESACCs generated in pounds and in rounds was calculated. ESACC market prices are compared against brass scrap market prices, the market price for selling ESACCs to ammunition remanufacturers, and the market price for selling ESACCs directly to civilian reloaders while factoring in shipping costs and capital costs required for SBSs.

Overview

The rest of this paper will consist of a literature review, methodology, discussion of scenarios, and a way forward. Chapter Two will review the literature collected and reviewed during the research for this paper. Chapter Three will explain the methodology used to calculate ESACC market price, shipping costs, distances between bases, capital costs of SBSs, and how optimal locations were calculated. Chapter Four will present the findings generated for each approach and display the results of each scenario. Lastly, Chapter Five will discuss overall findings, policy recommendations and suggestions for future research.

II. Literature Review

Overview

This literature review will explore research related to reverse logistics, ESACC generation, ESACC market price, and transportation costs. Additionally, research pertaining to the single source capacitated facility location problem (SSCFLP) will be reviewed. The purpose of this literature review is to explore each topic's contribution to the problem and discuss how the research will be used in the methodology outline in Chapter Three.

Current Process

Currently, the Air Force has not published overarching guidance on how bases should dispose of ESACCs other than to mutilate them at the point of sale in accordance with DoDM 4160.21. Each base is free to decide to give ESACCs to DLA or to purchase a deformer to deform ESACCs prior to sale. Allowing bases to create a local optimum does not mean that it is an optimal solution for the entire Air Force. In order for the Air Force to be an efficient organization the entire reverse logistics enterprise of ESACCs needs to be optimized, not just individual bases pursuing what works best for them.

Previously, the DoD recognized that there needed to be a reverse logistics network in place to handle ESACCs, and DLA was tasked with establishing the network. However, DLA was unable to pass an audit and thus established new reimbursement rules that have led to the current predicament. The services will have to decide if they should establish their own reverse logistics network or pass ESACC proceeds to DLA.

Reverse Logistics

Reverse logistics is a relatively new term, first coined by James Stock in 1992 (Stock, 1992). Reverse logistics encompasses operations that reuse, remanufacture or refurbish products. An understanding of a product's reuse or remanufacturing production process and the associated economics are essential to making optimal decisions when determining the ideal way to capture the end of life value for the particular product (Steeneck & Sarin, 2017). In the case of this paper, reverse logistics affects ESACCs because ESACCs must travel through the DoD transportation system to be processed by an SBS for resale to an entity that will then reuse the ESACC. The Air Force heavily utilizes reverse logistics operations to send equipment items from bases to depots to be repaired and remanufactured for continued use. This creates a cost-effective operation as equipment items are constantly recycled.

Unlike Air Force equipment items, ESACCs will not be remanufactured by the Air Force. Instead, they will exit the supply chain after being sold. The military services have long recognized the importance of reverse logistics operations and established the Defense Reutilization and Marketing Office (DRMO) to handle products that exit the supply chain. In most cases, items that are sold by DRMO are consolidated at another location before being sold. DLA Disposition Services now handles the functions formerly managed by DRMO.

In the civilian sector, reverse logistics operations can cost a company 7% of its gross sales. Third party logistics companies routinely make 12%-15% of their profits from providing reverse logistics solutions to their customers (Malone, 2005). Optimizing reverse logistics systems is important to maximize the value captured of the target product.

ESACC Generation

The Global Ammunition Control Point (GACP) receives reports on every ESACC expenditure through the Agile Munitions Support Tool (AMST). This data base provides a useful tool to determine how many ESACCs were expended at each base and of what type to determine the overall amount of ESACCs generated in both number and in pounds. These historical records provide data on ESACC expenditures have changed over time.

ESACC Market Price

Scrap Brass

The recycling yard at Lackland AFB has historically received an average of a $1.10 per pound for scrap brass that has been deformed and currently uses that rate as a cost planning factor. This is significantly less than scrap values found when conducting market research, which show a current market price of $2.12 a pound for yellow brass (Yellow Brass, 2019). However, the market rate does not include ESACCs as they pose a significant and costly hurdle, such as the removal of impurities from the brass including the nickel plating on the primer and gunpowder residue. Additionally, ESACCs can contain dirt, debris, and live rounds which add to the cost of recycling. Market data on ESACCs is scarce as very few locations outside of the military generate anywhere near the amount of ESACCs the military does and with DLA's lack of records, historical rates for government ESACCs are unknown. When conducting market research, it was discovered that only one place at the time of this writing offers a specific recycle rate for ESACCs at $.97 per pound (Brass Shells, 2019). The fact that only one system tracks the scrap market price of ESACC demonstrates the rarity of scrapping ESACC outside of government functions and the difficulty of accurately gauging market price. The current price listed is 11% below the cost planning factor that Lackland AFB utilizes. However, this price may be correct as Lackland AFB generates over 65 tons of ESACCs every year and has the ability to go direct to recycling yards to command the best price versus negotiating through middlemen. Due to this reason we will use Lackland AFB cost planning factor of $1.10 per pound for ESACCs when conducting the cost benefit analysis.

Selling ESACCs to Ammunition Remanufacturers

It is difficult to determine the price of ESACCs as scrap brass with only one location reporting a specific price of scrap ESACCs at $.97 per pound while overall yellow brass has a price of $2.12 per pound. Yellow brass has also fluctuated significantly in price with a reported one year low of $1.62 per pound for North America from the website Scrap Monster. Complicating prices even further are the ongoing trade tensions with China, which has been a major export market for US non-ferrous scrap.

These tensions have seen copper scrap prices fall 11% since April 2019, and China is planning on adding an additional 5% tariff to imported non-ferrous scrap in December of 2019 (Bera, 2019). The salvage value of ESACCs is highly dependent on international market price, and it is unclear how low prices will go before trade tensions are resolved.

When DLA processed ESACCs, it would put them out for bid through a government auction site. It is unknown what they historically received for intact ESACCs because they were unable to maintain oversight of the funds (Defense Logistics Agency, 2017). As part of the Brass to Bucks program, Virginia Tech reached out to a number of ammunition remanufacturers and assisted in generating estimates for what ESACCs are worth. The Air Force could pursue short term or long term contracts with these companies and sell the ESACCs to them in bulk. This approach provides less profit but also minimizes transportation cost and labor costs after processing the ESACCs.

An estimated 10 to 12 billion rounds are purchased annually by Americans (Bullet Control, 2019). It is not clear how many of those rounds are reloaded ammunition offered by companies like Freedom Munitions and Rainer Arms. These companies purchase once fired ESACCs from local gun ranges or the military and reload the casings to sell as remanufactured ammunition. Market data for this industry is not readily tracked. Virginia Tech conducted market research as part of the Brass to Bucks program and asked 40 different companies six specific questions:

1. From where do you currently purchase your once-fired brass?
2. How much do you currently pay for once-fired brass?
3. How much would you be willing to pay for mil-spec once-fired brass (e.g., Lake City)?
4. How much more would you be willing to pay for once-fired brass that has been sorted by caliber?
5. How many once-fired casings do you purchase in a year?
6. How much more would you be willing to pay for a large lot quantity (>1 million rounds) to avoid excess transportation costs?

The data returned by the survey was sparse with only four companies providing answers. For many companies, these prices are closely guarded as remanufactured ammunition is generally sold at a lower cost than manufactured ammunition and margins are slim. While market data is slim it does provide a starting point to determine the ESACC market price the Air Force can expect when selling to ammunition remanufacturers. As with ESACC scrap value, it should be assumed that these prices change depending on the current market conditions.

Selling ESACCs Directly To Civilian Reloaders

The Air Force could pursue selling ESACCs directly to civilian reloaders. Several companies purchase ESACCs in bulk from DLA and then resell them to consumers. Selling the Air Force's 51 million rounds (a twelfth of what the DoD expends annually) directly onto the consumer market could be fairly straight forward and add minimal steps to the handling of brass. The market research for selling ESACCs directly to consumers was conducted by searching for companies that offer ESACCs for sale to consumers. The companies were chosen at random and their ESACC sale price was recorded. Conducting this market research was the easiest of all three market valuations of ESACCs as prices are readily available. These prices do have hidden costs that the companies must account for such as shipping & handling, storage costs, and processing costs.

One way to sell ESACCs to civilian reloaders would be to price ESACCs at the same price as the lowest market price found online and leverage the United States Postal Service's 70 pound flat rate shipping boxes to sell ESACCs by caliber in 70 pound increments. This would increase handling cost from $12.80 to $17.60 a box or $.18 to $.25 a pound. Selling at the lowest price would ensure that the Air Force doesn't create a stockpile of ESACCs and minimizes the amount of market research required every year. It is assumed that the Air Force selling brass directly to consumers will not significantly disrupt the ESACC market since the quantity being sold is such a small amount. In the model created in Chapter Three, shipping & handling costs are partially taken into account, it is assumed storage costs are free, and processing costs are negated by SBSs which should allow the Air Force receive a larger profit percentage of the ESACC sale price compared to the companies that were researched.

Transportation Costs

Transportation costs are traditionally a huge driver in the overall costs of a reverse logistics operation. A cornerstone of reverse logistics is locating facilities to minimize associated transportation costs, which can represent up to 70% of all annual operation costs for reverse logistics enterprises (Dosal et al, 2013:97). The transportation cost data for this paper were provided by the DoD's Surface Deployment and Distribution Command (SDDC) and were calculated from Fiscal Year 2018 shipping data for Less than Truck Load (LTL), Freight of All Kinds (FAK) shipping rates across CONUS locations. SDDC does not have planning rates for LTL, FAK, however they did have a consulting firm conducting an analysis on what the DoD paid for shipping rates for FY 2018 CONUS FAK prices. The shipping costs were calculated using nine different weight bands to allow accurate calculations of shipping costs depending on the ESACC generation of the base. Interestingly, commercial contract rates for FAK are currently $2.14 per mile or assuming a 40,000 pound truck load, $.000053 impound/mile which is 39.3% cheaper than the lowest cost band from SDDC for LTL loads ($.000088 pound/mile) (National Rates, 2019). It appears that the DoD pays a premium for shipping, however this may occur because of the wait times accessing bases and the paperwork required to secure government contracts.

Inspection Requirements

To significantly reduce transportation costs and meet the requirement of two 100% independent inspections, expended ammunition casings will have to be certified expended by hand at the base of origin and labeled as Material Documented as Safe (MDAS). This will allow the DoD to transport scrap brass as general cargo and not as 1.4S class explosives. If the scrap brass is not documented as MDAS it would be considered 1.4S, which require two drivers and a satellite tracked truck to transport the brass, drastically increasing transportation costs.

Trade Security Requirements

To meet Trade Security Controls outside of the continental United States, ESACCs will be deformed or mutilated before sale in the local country. Sales will comply with the DoD Trade Security Controls outline in DoDI 2030.08. The goal of the Implementation Guidance for the Commercial Sale of ESACCs is to comply with host country laws that may prohibit the sales of ESACCs on the open market and to avoid cost prohibitive transportation to CONUS locations (Under Secretary of Defense, 2011).

Facility Location Problem

Determining the optimal facility location for the SBS will reduce transportation costs significantly and maximize the capital investment. The location problem explored in this paper will be the Single Source Capacitated Facility Location Problem (SSCFLP). The SSCFLP location problem is ideal for this particular problem because it allows for easy calculations by forcing each base to only ship to one other base and shipments can't be broken up. Additionally, it is designed to allow for facilities to have constraints to the amount of volume or product they can handle. This matches up with the SBS constraint that it can only handle 20 million ESACCs annually. The SSCFLP is a widely studied problem because of non-economic related reasons to serve customers from only one facility. These reasons include ensuring customer satisfaction, ease of scheduling, inability to separate customer shipments among multiple facilities, or other criteria.

The SSCFLP explored in this paper focuses on transportation cost differences between a single facility with multiple machines and having multiple facilities with single machines. In line with this the transportation cost variable is the exploration of how many SBSs should be purchased. When pursuing these variables, economies of scale have to be taken into account when consolidation of facilities occur which then impact optimal facility locations. Research conducted on regional food facility development showed that fewer locations for facilities were established as models allowed larger facilities to operate under economies of scale. However, when transportation costs increased, more facilities with less capacity become optimal due to the comparative advantages of less transportation to local markets (Ge et al, 2018:146). This demonstrates that if transportation costs are high, there will be a clear cost savings to establishing multiple facilities with a single SBS. In addition to modeling economies of scale, allowing multiple facilities to share the same location and reduce the initial fixed costs can be investigated. Models have shown that the larger the initial set-up costs, the more consolidation of facility locations occur because of high fixed costs (Wua et al, 2006:1239). The model presented in Chapter Three does not account for economies of scale. However, comparing multiple facilities versus a single facility will show the difference in transportation costs that economies of scale or reduction in fixed costs will need to overcome for a single facility to be more profitable than multiple facilities.

Other research into the Capacitated Facility Location Problem (CFLP) has identified that as total demand reaches total facility capacity in the network, the network becomes increasingly sensitive to demand changes. In the context of a SSCFLP problem where the primary decision variable is focused on transportation costs, this means that if the SBSs were located at separate facilities, as total demand reaches the maximum capacity the entire network can handle, transportation costs will increase as some bases are forced to go to non-optimal locations to avoid over capacitating optimal locations. Eventually the increased transportation costs might become so great that adding additional facilities at this point are justifiable even at a high cost per facility (Melkote and Daskin, 2001:494). ESACC generation has gone up by 15% between fiscal year 2016 and 2018. As ESACC generation continues to rise the overall network sensitivity will increase as it becomes closer to meeting the total network capacity. At this point, an additional study will need to be conducted to determine if another SBS should be purchased and where it should be located in the network or if another solution should be explored.

Research has also been conducted to determine that a capacitated facility has the ability to increase or stretch production (paying over-time, deferring maintenance, etc.) at the cost of increased production costs (Harkness and ReVelle, 2003:4). In the case of the SBS, this could be pursued if the network starts to become over capacitated and there is a lack of capital funding to purchase an additional

SBS. This solution could also be utilized should there be an unusual surge in ESACC generation that is not expected for following years. Stretching capacity, comes at increased cost for manpower (paying over-time) and increased wear and tear on the SBS. These increased costs may or may not be offset by the profit margin provided by ESACCs which depend on current market prices.

To reduce overall complexity of the model, the primary decision variables will focus on transportation costs, ESACC market price, and fixed costs. Economies of scale, network sensitivity, and stretching capacity will not be factored into the decision making variable but will be touched upon in the conclusion.

III. Methodology

Input Data

The optimal disposition of Air Force ESACCs involves three primary components: the market price of ESACCs, the capital cost of the SBS, and the shipping costs associated with shipping ESACCs to facility locations for processing. While other inputs such as labor costs, could be calculated into the methodology, these were excluded since they are a standard cost that occur at every location as opposed to being a critical variable cost that changes based on the parameters set. Future research may include these components. As these are the three primary quantifiable inputs into the facility system, each input will be explored in depth below.

The market price of ESACCs will be the starting point for this paper. Currently, the three ways to sell ESACCs are as scrap brass, intact casings to ammunition remanufacturers, or directly to civilian reloaders. The planning rate used for ESACC scrap price will be $1.10 per pound. It is assumed that this rate will remain steady for the foreseeable future and that any ESACCs not processed by a SBS will be sold on the market at $1.10 per pound.

As part of the Brass to Bucks program, the Virginia Tech conducted market research on ESACC sale price to large scale ammunition remanufacture. Forty companies were contacted with four returning the survey. The results are displayed in Table 1 below.

Table 1. Virginia Tech Market Research on Bulk ESACC Sale Price

Virginia Tech Market Research on Bulk ESACC Sale Price Per Pound					
Ammunition Reloaders	9x19	5.56x45	7.62x51	12.7x99	Amount Processed Annually
Blue Lakes	$1.80	$1.80	$2.00	$2.00	48,000,000
Defender Ammunitions*	$1.50	$1.50	$1.50	$1.50	N/A
Fast Brass**	$.80-$1.00	$0.80-$1.20	$0.80-$1.20	$0.80-$1.20	7,200,000-8,400,000
Peak Performance Ammunition	$2.15-2.25	$2.15-$2.25	$2.50-$2.60	$2.50-$2.60	8,400,000
Average	$1.60	$1.63	$1.76	$1.76	
Average Cash Price	$1.63	$1.67	$1.85	$1.85	
Average Realistic Price	$2.00	$2.00	$2.28	$2.28	
*Note Defender Ammunitions does not offer cash for stated prices, just in store credit.					
**Note Fast Brass values are an average of 20% lower to 20% higher than the current known scrap vale of ESACC					

Of the four companies that returned the survey, only three offer cash for ESACCs. Fast Brass offers a price that is close to the scrap price of ESACCs and is 40%-50% less than the average of the other two companies. Fast Brass will not be considered in some calculations as its market price is assumed to be unrealistic. Fast Brass gave a market price between $.80 and $1.00 for the caliber 9x19, this was averaged out to $.90. They also offer $.80-$1.20 per pound for calibers 5.56x45, 7.62x5, and 12.7x99 which was averaged out to $1.00 per pound. Lastly, Peak Performance offers $2.15-$2.25 per pound for 9x19 and 5.56x45 which averaged out to $2.20 per pound. For their 7.62x51 and 12.7x99 caliber they offer $2.50-$2.60 which was averaged to $2.55 per pound.

The average market price for each caliber was calculated by adding the specific market price or averaged market price offered by each company and dividing by the number of companies. The average cash price was calculated the same way, but Defender Ammunitions was left out since they did not offer cash value for the ESACCs. Lastly, the average realistic market price was calculated by leaving out both Fast Brass and Defender Ammunitions to generate a more accurate value of what ESACCs would be worth to remanufactures. For these market prices, shipping will not be taken into account as it is assumed that ammunition remanufacturers will pay for shipping from the facility to their company headquarters.

$$\text{Average Caliber Value} = \frac{\text{(Sum of All Market Prices)}}{\text{Number of Companies}}$$

Figure 1. ESACC Caliber Market Price Equation

To determine the market price of selling ESACCs intact directly to civilian reloaders, research was conducted on five companies that resell ESACCs. With each company, the market price of each calibers' ESACCs by pound was conducted by finding the largest bulk discount offered and multiplying the ESACC weight by the number of cartridges and then dividing by the price. Wherever possible, prices for once fired Lake City brass were calculated to provide a more accurate market price of military ESACCs. Three different prices were calculated, the average selling price of ESACCs, the lowest sale price found, and the lowest sale price of Lake City brass. The DoD predominately expends small arm ammunition from its Lake City manufacturing plant and this brass is prized by reloaders as it is of superior quality than commercial brass. This is seen by the fact the Lake City brass is identified as such on ESACC seller websites Diamond K Brass and Arm or Ally and commands a market premium.

$$\text{Price per pound} = \frac{\text{Bulk Price}}{((\text{Number of ESSACs} * \text{ESACC Weight in Grains})/7{,}000\text{ grains})}$$

Figure 2. ESACC Market Price per Pound Equation

Table 2. Bulk ESACC Sale Price

Bulk ESACC Sale Price From Online ESACC Distributors					
ESACC Market Sellers	9x19	5.56x45	7.62x51	12.7x99	Free Shipping and Cleaning
www.diamondkbrass.com	$3.21	$3.85	$4.06	$11.40	Yes
Diamond K Bulk Offerings in 55 Gallon	$2.99	$5.40	$4.56	N/A	No
www.evergladesammo.com	$4.05	$5.16	$5.14	$6.48	Yes
www.elitereloading.com	$2.92	$3.17	$6.46	N/A	No
www.capitalcartridge.com	$3.96	$3.71	$3.57	$7.20	Yes
www.armorally.com	$2.35	$4.68	$4.78	$5.61	No
Average	$3.25	$4.33	$4.76	$7.67	Average
Lowest Sale Price Found	$2.35	$3.17	$3.57	$5.61	
Lowest Sale Price of Lake City Brass	$2.35	$3.85	$4.06	$5.61	
Note - All calculations based on largest quanity discount offered by the company					
*Note - Lake City values calculated when possible are denoted by the price being highlighted					

For the Air Force to receive the higher profit per pound, it will have to provide shipping, possibly by leveraging the United States Postal Service 70 pound flat rate shipping boxes to sell ESACCs by caliber in 70 pound increments. This would increase costs from $0.18 to $0.25 per pound plus additional handling costs, however, the higher profit from selling ESACCs to consumers might offset this (Priority Mail, 2019). The Air Force could also negotiate with a different shipping company for a better rate. Additionally, there will be additional manpower costs to fill and ship boxes that will not be taken into account in this paper as they are difficult to accurately calculate.

To accurately calculate the market price of intact ESACCs, the amount of each ESACC type per fiscal year must be known. By creating an average percentage and multiplying it by the corresponding ESACC market price an average price per pound can be generated for analysis. This information was calculated by adding the amount of rounds fired each fiscal year of each caliber (9x19, 5.56x45, 7.62x51, and 12.7x99) and dividing by the total amount of rounds fired. These percentages were calculated for fiscal year 2016, 2017, and 2018. An average across all three years was calculated to use as the average expenditure of ESACCs for the intact ESACC market.

$$\text{Caliber Average} = \frac{\left(\frac{\text{FY ESACC Caliber}}{\text{FY Total ESACC}}\right)}{\text{3 Years}}$$

Figure 3. ESACC Average Expenditure by Year Equation

Table 3. ESACC Type by Percentage Expended by Fiscal Year

ESACC Type by Percentage Expended per Fiscal Year				
Round Type	2016 FY	2017 FY	2018 FY	Average
9x19	21.55%	21.78%	20.97%	21.43%
5.56x45	55.13%	54.82%	59.23%	56.39%
7.62x51	20.34%	20.26%	16.39%	19.00%
12.7x99	2.97%	3.12%	3.41%	3.17%

Utilizing the above table, the average market price per pound of ESACCs being sold to ammunition remanufacturers or directly to civilians can be calculated by taking ESACC market prices multiplied by the average percentage for each cartridge type and then adding all totals together. This generates an average ESACC price for ammunition remanufacturers of $2.06 per pound. By utilizing the lowest sale price, the Air Force ensures that it will sell its ESACCs in a timely manner and that the government does not compete with any private business while still maximizing profit. Using the same calculations, the average ESACC price for sale to civilian reloaders equals $3.62 per pound, but shipping will be subtracted at $.18 per pound, leaving the final number at $3.44 per pound. The final numbers that will be used in the rest of the paper’s calculations are: scrap brass $1.10 per pound, ESACCs sold to ammunition remanufacturers $2.06 per pound, and ESACCs sold to civilian reloaders $3.44 per pound.

Table 4. ESACC Market Price per Pound

Scrap Brass	$1.10
Ammunitions Remanufactures	$2.06
Civilian Reloaders	$3.44

ESACC Generation

ESACC generation was calculated for all Air Force bases for fiscal year 2016 - 2018. Each bases' expenditure data was pulled from Agile Munitions Support Tool (AMST) per fiscal year in Excel format. The raw data was then plugged into a separate excel sheet that searched for 55 pre-determined NSNs that denoted ESACCs. The total number of cartridges expended by NSN was multiplied by the empty shell weight of the particular ESACC and the total weight of ESACCs expended was recorded along with the number of cartridge casings generated. While every Air Force base expends ESACCs, only bases that expended more than 1,000 pounds of ESACCs annually on average were considered. Bases that were extremely close to each other, i.e. Duke Field and Eglin AFB, had their expenditures combined and reported as a single location to ease calculations. See figure 4 below for a map showing all locations used in this study.

Figure 4. CONUS Base Locations (Easy Map Maker, 2019)

The generation of ESACCs in fiscal years 2016 - 2018 was averaged to provide a planning estimate of ESACCs generated in both pounds and total rounds created. In total, 65 locations generated over 1,000 pounds of ESACCs and were considered to be nodes or possible facilities to place SBSs at. See Appendix A for every bases' expenditures per fiscal year and average. Between 2016 and 2018 overall ESACC generation rose by 15.5% (an additional 8,900,000 rounds expended) and pounds generated increased by 15.8% (an additional 142,000 pounds created). It is assumed that ESACC generation will remain steady as the overseas conflicts reduce in intensity and the Air Force continues to maintain its current size.

Capital Cost

In 2019 the Spent Brass Sorter from Cybernet Corporation was purchased for installation at Lackland AFB, Texas at a cost of $367,172 which includes transportation, installation, and initial training. Cybernet also offers a $30,000 a year warranty for up to 10 years to conduct annual training, replace high wear items, and fix broken parts. The SBS is capable of processing 10,000 rounds an hour or 20,000,000 rounds a year and only requires one individual to operate. It will be assumed that all SBSs can be purchased for $368,000 and that a 10 year warranty will be purchased as well. Assuming 2% annual inflation, the Net Present Value (NPV) of a SBS will be $642,390. After ten years of use, it is assumed the machine will not have any residual or salvage value and a new machine will have to be purchased to continue operations.

$$\text{NPV} = \frac{\text{Cash Flow}}{\text{1 + Discount Rate) * Time Perio}}$$

Figure 5. Net Present Value

Location Distances

Facility location distances were calculated using the DoD's Surface Deployment and Distribution Command (SDDC) product called Defense Table of Official Distances (DTOD). Each base was located on a map and its corresponding zip code was recorded. All 65 zip codes were entered into DTOD which returned every possible shipping distance between every base. By knowing every distance between each base and how many pounds of ESACCs each base expends, one can then calculate the shipping cost to each location in a per mile/per pound calculation.

Shipping Costs

As stated previously, the author also reached out to SDDC for historic Less than Truck Load (LTL), Freight of All Kinds (FAK) shipping rates across CONUS locations. The shipping costs were calculated using nine different weight bands to allow accurate calculations of shipping costs and are shown in Table 5 below.

Table 5. Fiscal Year 2018 SDDC LTL FAK Shipping Data

Shipment Weight in LBS	Weight Band	Median Cost/Lb/Mile
0-499	1	$0.00064964
500-999	2	$0.00027952
1,000-1,999	3	$0.00024687
2,000-4,999	4	$0.00023183
5,000-9,999	5	$0.00023674
10,000-19,999	6	$0.00018505
20,000-29,999	7	$0.00013238
30,000-39,999	8	$0.00012159
40,000+	9	$0.00008857

Facility Location Problem Methodology

If the Air Force purchased a SBS for every one of the 65 bases presented the Air Force could decrease shipping costs to zero. However, the ten year NPV on 65 SBSs is $41,755,350. If the Air Force sold ESACCs to civilian reloaders at top dollar ($3.44 per pound) then the ten year NPV of the expected profit would be $25,671,300. This is not cost effective and the Air Force will need to leverage LTL shipping costs and the placement of SBSs in optimal facility locations to minimize capital costs and shipping costs to increase profitability.

With the primary input data presented, the facility location problem will explore the interdependent relationships between the three inputs and attempt to determine the optimal facility system that maximizes profit. There are multiple ways to calculate where the optimal location for a single facility or multiple facilities should be located. Additionally, Lackland AFB is already receiving a SBS as part of the Brass to Bucks program. This location will be compared to optimal locations to provide the Air Force with a cost benefit analysis of operations being conducted there. This paper will explore single facility locations with one, two, or three SBSs. Additionally, it will explore two, three, and four facility locations, each with a single SBS. Since the average amount of ESACCs generated by the Air Force every year is 51 million and an SBS is capable of handling 20 million, it is assumed that no more than three SBSs will be required to handle all AF rounds. However, shipping costs may outweigh the capital costs of establishing a fourth SBS, so a facility location analysis will be performed with four SBSs to determine if establishing a fourth SBS is cost effective.

Table 6. Models to be Explored

	1 SBS	2 SBS	3 SBS
Single Facility	X	X	X
Lackland AFB	X	X	X
Two - Four Facilities	X		

When evaluating the data, it was discovered that if the expected market price of the processed brass is greater than \$1.91 per pound, then all bases' shipping combinations generate more revenue than the sum of the scrap brass market price plus shipping costs. Since the expected ESACC resale market price is \$2.06 and \$3.44 respectively, all shipping combinations will return a profit when processed. All calculations will be completed in Microsoft Excel using Solver with the Simplex LP program used to provide the optimal solution.

Single Facility Location Problem

The optimal single facility location problem with one, two, or three SBSs will be calculated with the following parameters. In Excel the objective function is set to minimize shipping costs with a constraint that the facility processes more than 19.9 million rounds but less than 20 million rounds per SBS. This bottom constraint was added because the equation needed a minimum constraint to ensure it processed as many rounds as possible. Additionally, a constraint is set that the SBS must process all of a base's rounds or none at all. The base that has the lowest shipping costs will receive the SBS. As a reminder, all shipping combinations generate profit so the more that the SBS processes, the more profit it will make.

The optimal single facility location problem with one, two, or three SBSs will be compared to establishing one, two, and three SBSs at Lackland AFB to generate a cost analysis to determine the benefit or drawback of establishing a facility location at Lackland AFB.

[SSCFLP] Minimize $\sum F_L((B_1\text{-}B_{65})S_C$

Subject to:

$F_L \leq 20{,}000{,}000$ SBSx

$F_L \geq 19{,}900{,}000$ SBSx

$B_1\text{-}B_{65}$ = Single Source

Where:

F_L = Facility location

$B_1\text{-}B_{65}$ = All possible shipping distances and weights

S_C = Variable shipping cost dependent on weight

SBSx = Number of SBS assigned to the location problem with x being a variable integer

Figure 6. The Single Facility Location Problem

Multiple Facility Location Problem

To generate the optimal two facility solution with each facility having a single SBS, the equation will start by determining the optimal placement of the first facility. All locations that ship to the first facility will be eliminated from possible locations for the second facility. As with the single facility location problem, in Excel the objective function is set to minimize shipping costs with a constraint that the facility processes more than 19.9 million rounds but less than 20 million rounds per facility location. The single source constraint remains that the SBS must process all of a base's rounds or none at all. The base that has the lowest shipping costs will receive the SBS. The problem will then repeat with a second iteration, ignoring the bases assigned to the first facility, and locating the second SBS at the facility with the lowest shipping costs. This will be conducted for the first location and the second location.

[SSCFLP] Minimize $\sum F_{L1}((B_1\text{-}B_{65})S_C + F_{L2}((B_1\text{-}B_{65\text{-}FL1})S_C$

Subject to:

$F_L \leq 20{,}000{,}000$ SBS

$F_L \geq 19{,}900{,}000$ SBS

$B_1\text{-}B_{65}$ = Single Source

Where:

F_{L1} = Facility One

F_{L2} = Facility Two

$B_1\text{-}B_{65}$ = All possible shipping distances and weights

$B_1\text{-}B_{65\text{-}FL1}$ = All possible shipping distances and weights minus bases that ship to F_{L1}

S_C = Variable shipping cost dependent on weight

Figure 7. Two Facility Location Problem

The three facility location problem will follow the equation of the two facility location problem with the addition of a third facility that is constrained to handle the rest of the ESACCs generated. This will be expressed as:

[SSCFLP] Minimize $\sum F_{L1}((B_1\text{-}B_{65})S_C + F_{L2}((B_1\text{-}B_{65\text{-}FL1})S_C + (F_{L3}((B_1\text{-}B_{65\text{-}FL1\text{-}FL2})S_C$

Subject to:

$F_{L1\,\&\,2} \leq 20{,}000{,}000$ SBS

$F_{L1\,\&\,2} \geq 19{,}900{,}000$ SBS

F_{L3} = Remaining ESACCs

B_1-B_{65} = Single Source

Where:

F_{L1} = Facility One

F_{L2} = Facility Two

F_{L3} = Facility Three

B_1-B_{65} = All possible shipping distances and weights

B_1-$B_{65\text{-}FL1}$ = All possible shipping distances and weights minus bases that ship to F_{L1}

B_1-$B_{65\text{-}FL1\text{-}FL2}$ = All possible shipping distances and weights minus bases that ship to F_{L1}&F_{L2}

S_C = Variable shipping cost dependent on weight

Figure 8. Three Facility Location Problem

To explore the creation of four facilities with a single SBS the facilities will be constrained to process more than 12.9 million rounds but less than 13 million rounds. These constraints were created by dividing the average annual expenditures (51.9 million rounds) by four facilities which generated an average of 12.9 million rounds to be processed at each location. As with the other multiple facility location problems, once a facility has been chosen, the bases shipping to it will be eliminated from the next iteration. In Excel the objective function is set to minimize shipping costs while the bases can only ship to one location.

[SSCFLP] Minimize $\sum F_{L1}((B_1\text{-}B_{65})S_C + F_{L2}((B_1\text{-}B_{65\text{-}FL1})S_C + (F_{L3}((B_1\text{-}B_{65\text{-}FL1\text{-}FL2})S_C + (F_{L4}((B_1\text{-}B_{65\text{-}FL1\text{-}FL2\text{-}FL3})S_C$

Subject to:

$F_{LX} \leq 13{,}000{,}000$ SBS

$F_{LX} \geq 12{,}900{,}000$ SBS

$B_1\text{-}B_{65}$ = Single Source

Where:

F_{L1} = Facility One

F_{L2} = Facility Two

F_{L3} = Facility Three

F_{L4} = Facility Three

$B_1\text{-}B_{65}$ = All possible shipping distances and weights

$B_1\text{-}B_{65\text{-}FL1}$ = All possible shipping distances and weights minus bases that ship to F_{L1}

$B_1\text{-}B_{65\text{-}FL1\text{-}FL2}$ = All possible shipping distances and weights minus bases that ship to F_{L1} & F_{L2}

$B_1\text{-}B_{65\text{-}FL1\text{-}FL2\text{-}FL3}$ = All possible shipping distances and weights minus bases that ship to F_{L1} ; F_{L2} & F_{L3}

S_C = Variable shipping cost dependent on weight

Figure 9. Four Facility Location Problem

Presenting Results

All results for each facility location problem will be displayed using a ten year Net Present Value (NPV) calculation. The ten year time frame was chosen as this is when the SBS warranty runs out and provides a convenient timeline to end the analysis.

The ten year NPV will be calculated for the SBS capital cost, total profit, total shipping costs, and the sensitivity analysis with an assumed 2% rate of inflation. While inflation rates can change depending on market conditions for the last decade inflation rates have remained between .7% - 3% (Current Inflation Rates, 2019). It is assumed that this inflation rate holds for the next decade during the analysis.

Each problem will display the ten year NPV for salvage value, ESACC market price when selling to ammunition remanufacturers, and the ESACC market price when selling to civilian reloaders. When exploring only one or two SBS machines for the Air Force, any rounds that are unable to be processed will be shown with a ten year salvage value NPV. Revenue will be calculated by multiplying the pounds of ESACCs processed by the corresponding method of sale. It will be assumed that ESACC generation and market price will remain the same over the ten year span.

At the bottom of each results table the amount of time in years to pay off the ten year NPV of a SBS will be calculated and displayed. This will be known at the Break Even Point (BEP). To calculate the BEP, the ten year NPV of the resell method will be divided by ten. That number will be used to divide the SBS capital cost NPV and determine the amount of years required to pay off the machine. Total profit will be calculated by subtracting the shipping costs and capital investment costs from the total ESACC sale price and will be recorded as well.

A sensitivity analysis will be conducted on each problem. There will be two types of sensitivity analysis, a best case and a worst case. The best case assumes ESACC generation rises by 15% and all associated market price increases 15%. The worst case assumes ESACC generation falls 15% and the associated market price decreases 15%. These sensitivity analyses will show time to reach BEP changes as ESACC generation and market valuation change.

Assumptions and Limitations

There are several assumptions in this paper. The first one is that inflation will remain relatively constant over the next ten years. There is no guarantee of this occurring and higher or lower than average inflation can change the NPV calculations. Additionally, it is assumed that all data gathered from AMST was accurate and that ESACC generation will not change significantly over the next ten years and will remain steady. In conjunction with ESACC generation, it is also assumed that none of the 65 bases will be closed over the next ten years and each base will continue to generate roughly the same amount of ESACCs. The last assumption is the DoD LTL FAK shipping rates will remain similar over the next several years.

The model faces limitations in researching and determining the scrap market price and market price of ESACCs sold to ammunition remanufacturers as data generated by the government lacked audit compliance to the point that DLA was forced to change its reimbursement rules (Defense Logistics Agency, 2017). Market research was conducted to determine accurate estimates to use, however, they were hampered by small data sizes and lacked accurate data at times.

Finally, the model does not take labor costs into account for two reasons. First, the current system in place does not consider labor costs and it would be difficult to poll 65 different locations to determine what each location spends on labor every year. The second is that until the Air Force SBS is up and running, it is difficult to determine how much labor a SBS consumes. While an SBS can be run by only one person, it is doubtful that one person could also conduct sales, receive brass from other bases, and conduct other tasks. Without an SBS to conduct a study on, all labor costs projections would not have been based on empirical evidence.

IV. Data Analysis

Overview

This chapter will analyze the results of the models outlined in Chapter 3. Each facility location will show the ten year NPV of capital investment, shipping costs, expected profit, and scrap value of non-processed ESACCs. Shipping costs, which are a reflection of each base expenditure by weight, distance traveled, and variable LTL shipping costs were used as the determining factor for facility locations. The sensitivity analysis will demonstrate how well the facility location solution can handle an increase or decrease in ESACC generation and market price. Additionally, the sensitivity analysis will showcase the change in the breakeven point for the capital investment as the solution responds to changes.

Single Facility with One SBS

The optimal facility location to place one SBS is Lackland AFB, Texas. This location will process 3.1 million pounds of ESACCs over ten years for a ten year NPV shipping cost of $111,083. Lackland AFB is the largest generator of ESACCs in the United States Air Force so it is no surprise that the model minimized shipping costs by placing a SBS at this location. With this solution, the Air Force will pay $.036 per pound to ship ESACCs to Lackland AFB over ten years. Since Lackland AFB is the optimal solution there is no need to compare it to any other location possibility. This location also shows robust insensitivity to market or ESACC generation decrease with an increase of .43 (ammunition remanufacturers) or .32 (civilian reloaders) years to pay off the SBS in the worst case scenario. This solution leaves 5 million pounds of ESACCs unprocessed to be sold as brass scrap.

Table 7. Single Facility with One SBS Solution

Shipping to Lackland AFB					
	SBS NPV	Shipping Cost	Remanufacturer	Civilian Reloader	Scrap
Ten Year NPV	$642,390.79	$111,083.45	*$5,774,645.14	*$9,643,096.73	*$4,961,121.50
BEP in Years			1.11	0.67	N/A
Total Profit			$5,021,170.90	$8,889,622.49	N/A
Sensitivity Analysis					
			Remanufacturer	Civilian Reloader	Scrap
15% Fall in Generation & Price			*$4,172,181.11	*$6,967,137.39	*$3,584,410.29
BEP in Years			1.54	0.92	N/A
15% Rise in Generation & Price			*$7,636,968.19	*$12,752,995.43	*$6,561,083.19
BEP in Years			0.84	0.50	N/A

*Revenue from ESACC sales

Single Facility with Two SBSs

The optimal facility location to place two SBSs is Little Rock AFB, Arkansas. This location will process 5.9 million pounds of ESACCs over ten years for a ten year NPV shipping cost of $536,921 with the use of two SBSs. With this solution, shipping costs rise to $.091 per pound to ship ESACCs to Little Rock AFB over ten years. Expected profit from selling ESACCs to ammunition remanufacturers after capital costs and shipping is $9,394,249. Selling ESACCs to civilian reloaders generates a total profit of $16,907,848 while leaving only 2.2 million pounds of ESACCs to be sold as scrap brass. Lastly, in the worst case scenario, BEP increases by .47 (ammunition remanufacturers) and .28 (civilian reloaders) years which is slightly more than the solution to the Single Facility with One SBS solution.

Table 8. Single Facility with Two SBSs Solution

Shipping to Little Rock AFB					
	SBS NPV	Shipping Cost	Remanufacturer	Civilian Reloader	Scrap
Ten Year NPV	$1,284,781.58	$536,921.33	*$11,215,951.80	*$18,729,550.58	*$2,219,746.34
BEP in Years			1.15	0.69	N/A
Total Profit			$9,394,248.89	$16,907,847.67	N/A
Sensitivity Analysis					
			Remanufacturer	Civilian Reloader	Scrap
15% Fall in Generation & Price			*$7,941,454.67	*$13,261,458.29	*$1,571,691.39
BEP in Years			1.62	0.97	N/A
15% Rise in Generation & Price			*$14,536,434.33	*$24,274,434.03	*$2,876,902.24
BEP in Years			0.88	0.53	N/A

*Revenue from ESACC sales

Lackland AFB with Two SBSs

Lackland AFB is extremely competitive with Little Rock AFB when two SBSs are located there. Surprisingly, Lackland AFB processes 6.4 million pounds of ESACCS, an increase of 500,000 pounds when compared to Little Rock AFB, for a ten year NPV shipping cost of $583,221. Shipping costs remain the same at $.091 per pound to ship ESACCs to Lackland AFB because the increase in shipped ESACCs offset the increase in shipping costs. Total profit when selling ESACCs to ammunition remanufacturers rises to $10,007,753, an increase of $613,504 when compared to Little Rock AFB. Profit from the sale of ESACCs to civilian reloaders equals $17,963,356 which is $1,055,508 more than Little Rock AFB. The BEP for Lackland AFB decreases by .07 (ammunition remanufacturers) and 0.04 (civilian reloaders) years when compared to the optimal. Lackland AFB also demonstrates less sensitivity to market conditions with smaller changes in the BEP when compared to Little Rock AFB.

Table 9. Lackland AFB with Two SBSs Solution

Shipping to Lackland AFB					
	SBS NPV	Shipping Cost	Remanufacturer	Civilian Reloader	Scrap
Ten Year NPV	$1,284,781.58	$583,221.75	*$11,875,755.67	*$19,831,358.99	*$2,219,746.34
BEP in Years			1.08	0.65	N/A
Total Profit			$10,007,752.35	$17,963,355.66	N/A
Sensitivity Analysis					
			Remanufacturer	Civilian Reloader	Scrap
15% Fall in Generation & Price			*$8,580,233.48	*$14,328,156.87	*$1,230,595.92
BEP in Years			1.50	0.90	N/A
15% Rise in Generation & Price			*$15,705,686.88	*$26,226,972.27	*$2,252,544.09
BEP in Years			0.82	0.49	N/A

*Revenue from ESACC sales

Single Facility with Three SBSs

The optimal facility location to place three SBSs is Tinker AFB, Oklahoma. This location will process 8.1 million pounds of ESACCs over ten years for a ten year NPV shipping cost of $1,016,230. This comes out to $.125 per pound to ship ESACCs to Tinker AFB over a ten year period. This solution has a total profit of $12,122,070 when selling ESACCs to ammunition remanufacturers and $22,214,474 when selling ESACCs to civilian reloaders. Compared to the optimal single facility with two SBS solution, this solution takes .13 (ammunition remanufacturers) and .08 (civilian reloaders) years to reach the BEP. However, the sensitivity analysis shows that the best and worst case scenarios are still in line with the other facility location models. This solution also has the potential to process an additional 8 million ESACCs annually before reaching full capacity.

Table 10. Single Facility with Three SBSs Solution

Shipping to Tinker AFB					
	SBS NPV	Shipping Cost	Remanufacturer	Civilian Reloader	Scrap
Ten Year NPV	$1,927,172.37	$1,016,230.88	*$15,065,472.68	*$25,157,876.71	$-
BEP in Years			1.28	0.77	N/A
Total Profit			$12,122,069.44	$22,214,473.47	N/A
Sensitivity Analysis					
			Remanufacturer	Civilian Reloader	Scrap
15% Fall in Generation & Price			*$10,884,804.01	*$18,176,565.92	$-
BEP in Years			1.77	1.06	N/A
15% Rise in Generation & Price			*$19,924,087.62	*$33,271,291.95	$-
BEP in Years			0.97	0.58	N/A

*Revenue from ESACC sales

Lackland AFB with Three SBSs

When compared to establishing a single facility location at Lackland AFB, ten year NPV shipping costs rise to $1,130,820, an increase of $114,590 when compared to Tinker AFB. Shipping cost increase to $.14 per pound of shipped ESACCs when compared to Tinker AFB over the ten year period. Profit decreases to $12,007,480 when selling ESACCs to ammunition remanufacturers and to $22,099,884 when selling ESACCs to civilian reloaders. Otherwise, Lackland AFB possess the same BEP and sensitivity analysis of Tinker AFB.

Table 11. Lackland AFB with Three SBSs Solution

Shipping to Lackland AFB					
	SBS NPV	Shipping Cost	Remanufacturer	Civilian Reloader	Scrap
Ten Year NPV	$1,927,172.37	$1,130,820.22	*$15,065,472.68	*$25,157,876.71	$ -
BEP in Years			1.28	0.77	N/A
Total Profit			$12,007,480.09	$22,099,884.12	N/A
Sensitivity Analysis					
			Remanufacturer	Civilian Reloader	Scrap
15% Fall in Generation & Price			*$10,884,804.01	*$18,176,565.92	$ -
BEP in Years			1.77	1.06	N/A
15% Rise in Generation & Price			*$19,924,087.62	*$33,271,291.95	$ -
BEP in Years			0.97	0.58	N/A

*Revenue from ESACC sales

Two Facilities with a Single SBS

Locating a SBS at Lackland AFB and Dobbins ARB allows for 6 million pounds of ESACCs to be processed over ten years with a ten year shipping NPV of $376,446. When comparing this solution to the single facility creation at Little Rock AFB, Lackland AFB and Dobbins AFB process an additional 100,000 pounds of ESACCs while saving $160,475 in transportation costs. This comes out to $.062 per pound of shipped ESACCs over the ten year shipping period. The sensitivity analysis for this solution shows a slight improvement in the BEP when compared to the Little Rock Facility.

Table 12. Two Facilities with a Single SBS Solution

Shipping to Lackland AFB & Dobbins ARB					
	SBS NPV	Shipping Cost	Remanufacturer	Civilian Reloader	Scrap
Ten Year NPV	$1,284,781.58	$376,446.24	*$11,140,234.48	*$18,603,110.01	*$2,096,000.98
BEP in Years			1.15	0.69	N/A
Total Profit			$9,479,006.67	$16,941,882.20	N/A
Sensitivity Analysis					
			Remanufacturer	Civilian Reloader	Scrap
15% Fall in Generation & Price			*$8,048,819.41	*$13,440,746.98	*$1,514,360.71
BEP in Years			1.60	0.96	N/A
15% Rise in Generation & Price			*$14,732,960.10	*$24,602,612.99	*$2,771,961.30
BEP in Years			0.87	0.52	N/A

*Revenue from ESACC sales

Three Facilities with a Single SBS

The optimal solution for selecting three facility locations, each with a single SBS, is Lackland AFB, Dobbins ARB, and Nellis AFB. With these three locations, 8.1 million pounds of ESACCs are processed for a ten year NPV shipping cost of $603,669. This come out to $.075 per pound to ship ESACCs, a decrease of $.05 per pound when compared to the single facility location solution of Tinker AFB. Total profit when selling ESACCs to ammunition remanufacturers rises to $12,534,631 and when selling ESACCs to civilians, profit equals $22,627,035.

Table 13. Three Facilities with a Single SBS Solution

Shipping to Lackland AFB, Dobbins ARB, and Nellis AFB					
	SBS NPV	Shipping Cost	Remanufacturer	Civilian Reloader	Scrap
Ten Year NPV	$1,927,172.37	$603,669.25	*$15,065,472.68	*$25,157,876.71	$ -
BEP in Years			1.28	0.77	N/A
Total Profit			$12,534,631.06	$22,627,035.09	N/A
Sensitivity Analysis					
			Remanufacturer	Civilian Reloader	Scrap
15% Fall in Generation & Price			*$10,884,804.01	*$18,176,565.92	$ -
BEP in Years			1.77	1.06	N/A
15% Rise in Generation & Price			*$19,924,087.62	*$33,271,291.95	$ -
BEP in Years			0.97	0.58	N/A

*Revenue from ESACC sales

Four Facilities with a Single SBS

The optimal solution for the Four Facilities with a Single SBS is Lackland AFB, Pope AFB, Nellis AFB, and Whiteman AFB. In this solution, 8.1 million pounds of ESACCs are processed for a ten year NPV shipping cost of $557,193, a reduction of $46,106 when compared to the three facility optimal location solution. Shipping costs drop to $.069 per pound of ESACCs shipped when compared to the three facility location, however, BEP in years increased by .43 (ammunition remanufacturers) and .25 (civilian reloaders) years when compared to the Three Facility with One SBS.

Table 14. Four Facilities with a Single SBS Solution

Shipping to Lackland AFB, Pope AFB, Nellis AFB, and Whiteman AFB					
	SBS NPV	**Shipping Cost**	**Remanufacturer**	**Civilian Reloader**	**Scrap**
Ten Year NPV	$2,569,563.16	$557,193.85	*$15,065,472.68	*$25,157,876.71	$ -
BEP in Years			1.71	1.02	N/A
Total Profit			$11,938,715.67	$22,031,119.70	N/A
Sensitivity Analysis					
			Remanufacturer	**Civilian Reloader**	**Scrap**
15% Fall in Generation & Price			*$10,884,804.01	*$18,176,565.92	$ -
BEP in Years			2.36	1.41	N/A
15% Rise in Generation & Price			*$19,924,087.62	*$33,271,291.95	$ -
BEP in Years			1.29	0.77	N/A

*Revenue from ESACC sales

V. Conclusions and Recommendation

Overview

Chapter Five will discuss the results shown in Chapter Four and make recommendations based on those findings. Specifically, the author will make the case for single facility locations at Lackland AFB or Tinker AFB which contradict model results from Chapter Four. Additionally, the author will recommend if the Air Force should pursue selling ESACCs to Ammunition Remanfacturers or Civilian Reoaders. Future research will be suggested to improve the establishment of a reverse logistics network on Air Force ESACCs.

Findings

Table 15. All Model Results and Expected Profit Combinations

	Remanufacturer			Civilian Reloader		
	Expected Profit	Low Estimate	High Estimate	Expected Profit	Low Estimate	High Estimate
Single Facility w/One SBS	$5,021,170.90	$3,418,706.87	$6,883,493.95	$8,889,622.49	$6,213,663.15	$11,999,521.19
Single Facility w/Two SBSs	$9,394,248.89	$6,119,751.76	$12,714,731.42	$16,907,847.67	$11,439,755.38	$22,452,731.12
Lackland AFB w/Two SBSs	$10,007,752.34	$6,712,230.15	$13,837,683.55	$17,963,355.66	$12,460,153.54	$24,358,968.94
Single Facility w/Three SBSs	$12,122,069.43	$7,941,400.76	$16,980,684.37	$22,214,473.46	$15,233,162.67	$30,327,888.70
Lackland AFB w/Three SBSs	$12,007,480.09	$7,826,811.42	$16,866,095.03	$22,099,884.12	$15,118,573.33	$30,213,299.36
Two Facilities w/One SBS	$9,479,006.66	$6,387,591.59	$13,071,732.28	$16,941,882.19	$11,779,519.16	$22,941,385.17
Three Facilities w/One SBS	$12,534,631.06	$8,353,962.39	$17,393,246.00	$22,627,035.09	$15,645,724.30	$30,740,450.33
Four Facilities w/One SBS	$11,938,715.67	$7,758,047.00	$16,797,330.61	$22,031,119.70	$15,049,808.91	$30,144,534.94

Six different models, and the results accounting for the existing facility at Lackland AFB, were compared against each other to determine the optimal facility location solution for the Air Force's ESACC problem. The Air Force's current plan to establish the first facility at Lackland AFB matches exactly with the optimal single facility with one SBS solution determined by the model. Placing an SBS at Lackland AFB also provides the lowest shipping cost of just $.036 per pound of ESACCs processed by Lackland AFB. This makes the location less sensitive to future changes in shipping costs since ~40% of all ESACCs processed are generated on site.

Solutions to the single facility with two SBSs, two facilities with one SBS, and Lackland AFB with two SBSs had total profits within 10% of each other. The two facilities with one SBS solution managed to save over $160,000 in shipping costs compared to the other two solutions making it the most ideal for the Air Force.

The solution of the three facilities with one SBS provides the most transportation savings to the Air Force, generating over $400,000 in savings when compared to establishing three SBSs at Tinker AFB. The solution easily processes all ESACCs generated by the Air Force and should be less sensitive to changes in shipping costs since ESACCs travel less distance to a facility.

The solution to the four facilities with one SBSs proved that unless the Air Force was going to generate larger quantities of ESACCs it is not worthwhile to invest in a fourth SBS. The solution saved less than $50,000 in transportation cost over ten years when compared to the optimal three facilities with one SBS solution for an increased capital investment cost of $642,000. The increase in the BEP is not ideal and the entire network operates at 65% capacity.

Overall, the transportation savings generated by creating multiple facilities versus consolidating all SBSs to one facility was surprisingly low. The solution to the four facilities with one SBS saved less than $500,000 over the ten years of operation when compared to Tinker AFB with three SBSs. As noted previously, in some reverse logistics systems, transportation costs can be as high as 70% of all operational costs (Dosal et al, 2013:97). In nearly every solution, transportation costs were less than half the capital investment costs of the SBS and reduced total profit by less than 10%.

Recommendations

Location Recommendations

It is the author's recommendation that if the Air Force decides to only purchase one SBS machine than it should be located at Lackland AFB. This is the optimal location for a single SBS and should be the most insensitive location to any changes in shipping costs since ~40% of all ESACCs are generated on site. Currently the Air Force is planning on locating a single SBS at Lackland AFB as part of the Brass to Bucks program, this location was chosen because Lackland AFB expends the most ESACCs of any Air Force base. It was a coincidence that it also had the cheapest shipping costs according to the model.

Should additional funding be secured for a second SBS, it should be located at Lackland AFB as well since the shipping costs are only $46,300 more over a ten-year NPV period than the optimal location of Little Rock AFB. The additional transportation costs should be easily offset by housing two SBSs in the same building. This solution is also ideal if the Air Force believes that ESACC generation will decrease and only two SBSs will be needed.

If the Air Force funds three SBS machines that they should all be located at Tinker AFB. The model estimates that Tinker AFB would save $114,000 in shipping costs over ten-years when compared to Lackland AFB operating three SBSs. The shipping costs savings would pay for the relocation of one or two SBSs from Lackland AFB to Tinker AFB.

The Air Force should fund three SBS machines because even in the worst case scenario, it only takes 1.77 years to reach the BEP. If current market conditions stay the same, the Air Force can expect to make between $12 million and $22 million over the next ten years depending on the resale method.

This recommendation goes directly against the solution of the Three Facilities with One SBS where the optimal solution is establishing facilities at Lackland AFB, Dobbins ARB, and Nellis AFB. The reason for this recommendation is because the increased cost of shipping to Tinker AFB, $412,561 ten year NPV, should be offset by efficiencies gained. Efficiencies can be gained in three ways: the fixed cost of the building to house the SBS, SBS efficiencies, and management and personnel efficiencies. The construction of a building to house the SBS was not taken into account with the model because building costs vary by location and some locations may already have a building that is capable of housing a SBS. Additionally, needing only one building to house three SBSs should be cheaper than construction and maintenance of three separate buildings in different locations. Running three SBSs at the same location may allow the Air Force to negotiate with Cybernet Corporation for a reduced warranty cost since part of the warranty is the replacement of wear and tear items. By visiting just one location, Cybernet should save money on servicing three SBSs versus servicing three SBSs located around the country. Lastly, locating three SBSs at one location should allow some manpower and management savings compared to three separate facilities. In total, the efficiencies gained by having one facility only need to be worth more than $413,000 over a ten year NPV to make it worthwhile.

There are several non-economic related factors that make a single facility location ideal. Specifically, records and financial documents would be processed through the same location, hopefully avoiding any audit errors which plagued DLA. Additionally, a single facility would be less sensitive as ESACC generation reaches overall network capacity because all bases would ship to one location. In a three facility location, should one location reach full capacity and the overall network reach close to full capacity, the entire network becomes more sensitive to ESACC generation changes. This can cause bases to ship to location that are not the optimal because the optimal location is at full capacity.

Creating only one facility does have drawbacks. Specifically, one location would be more sensitive to an increase in shipping costs versus a three facility location because of its non-optimal position to minimize shipping costs. Additionally, if the Air Force was to increase ESACC generation then shipping costs would become more pronounced and reduce total profitability. Finally, a single facility is more sensitive to changes in where ESACCs are expended. Should Air Force Basic Military Training and Security Force's Training be relocated from Lackland AFB to another location, the single facility location may become less than ideal. The Air Force would have to accept the reduced total profit because of the increased shipping costs or pay to relocate the single facility to the new, optimal location.

ESACC Sale Type

The Air Force should aggressively pursue establishing the required regulatory guidance to sell ESACCs to civilian reloaders. In every solution and in the sensitivity analysis, selling ESACCs to civilian reloaders increased profitability by at least 25% and provided a faster BEP when compared to selling to ammunition remanufacturers. Regardless of the Air Force's decision to purchase just one SBS or three SBSs, the Air Force should pursue selling ESACCs to civilian reloaders because of the higher profit margin.

If the Air Force established a single facility at Tinker AFB, the difference in total profit between selling ESACCs to ammunition remanufacturers versus selling ESACCs to civilian reloaders is ~$10,000,000. Selling to civilian reloaders also decreases the BEP for Tinker AFB by .51 years. While the total profit takes into account shipping costs, SBS costs, and shipping costs to civilian reloaders, it doesn't take into account the manpower costs associated with filling orders or the costs of building a website to sell ESACCs through. These costs should easily be offset by the increased profit. Additionally, the higher profit generated by selling ESACCs to civilian reloaders would allow the Air Force to make the case for a fourth SBS if ESACC generation becomes more the capacity of the three SBSs installed. Conversely, the higher profit might allow the Air Force to make the case for over-utilization of the SBSs and to pay overtime to process excess ESACCs rather than purchase a fourth SBS.

Future Research

Future research could build upon this study in a multitude of different ways. First, a researcher could refine the model and using a green field approach, determine optimal locations outside of Air Force Bases utilizing software like CPLEX. The model doesn’t explore multiple bases consolidating ESACCs before shipping to a facility. This could potentially generate massive savings as the least expensive shipping band is 800% cheaper than the most expensive shipping band. Additionally, the model doesn’t use forecasting techniques and assumes bases’ ESACC generation will remain static. Utilizing a model that predicts future demand increases based on historical data would ensure that shipping costs are minimized as ESACC demand changes. Furthermore, other shipping companies such as FEDEX could be contracted to ship ESACCs to civilian reloaders at a reduced rate.

In addition to the above methodologies, Cybernet does build ATACS and SBSs that are portable by semi-tractor. Future research could explore the Mobile Modular Capacitated Facility Location Problem (MMCFLP) and determine the optimal route that a fleet of mobile SBS should take to minimize shipping costs and maximize profit.

Summary

This research provides the Air Force with a model that provides different options to implement the Brass to Bucks program. The findings of this research recommend that three SBSs be located at Tinker AFB. However, large transportation savings can be achieved if the SBSs are decentralized into three different facilities. It was shown that selling to civilian reloaders generates the most profit, and DoD shipping rates allow for inexpensive consolidation of ESACCs to be processed by facility locations possessing SBSs.

Appendix A. ESACC Expenditures per Base

Air Force Base	DoDAAC	ZipCode	3 Year Weight	3 Year Expended	FY18 Weight in Lbs	FY18 ESACCS Expended	FY17 Weight in Lbs	FY17 ESACCS Expended	FY16 Weight in	FY16 ESACCS Expended
ALTUS AFB	FV4419	73523	2,881	197,369	4,305	263,017	2,195	167,733	2,144	161,358
ANDREWS AFB	FV4425/FV6511	20762	14,688	1,184,602	17,363	1,377,053	13,472	1,094,595	13,229	1,082,158
BARKSDALE AFB	FV4608/FV6646	71110	6,855	534,482	9,468	732,635	5,156	401,139	5,941	469,671
BEALE AFB	FV4686	95903	7,049	516,241	8,326	583,161	6,705	506,409	6,115	459,152
CANNON AFB	FV4855	88103	22,194	1,382,157	24,952	1,646,768	21,546	1,285,654	20,083	1,214,050
CHARLESTON AFB	FV4418	29404	10,271	777,640	12,038	897,098	9,776	749,937	9,000	685,885
COLUMBUS AFB	FV3022	39705	1,320	111,012	802	65,829	1,777	149,271	1,381	117,935
CREECH AFB	FV4960	89018	2,105	173,282	2,134	174,560	2,052	169,981	2,129	175,305
DAVIS-MONTHAN	FV4877	85707	39,257	1,528,623	46,209	1,739,738	31,943	1,356,123	39,617	1,490,008
DOBBINS ARB	FV6703	30069	2,086	164,073	2,235	177,243	2,374	187,494	1,651	127,481
DOVER AFB	FV4497	19902	6,183	474,762	8,472	636,335	5,155	400,574	4,924	387,376
DUKE FLD 3/EGLIN AFB	FV6628/FV2823	32542	4,128	317,585	6,194	488,339	2,709	207,978	3,481	256,438
DYESS AFB	FV4661	79606	5,748	449,752	8,467	662,972	4,710	362,631	4,066	323,654
EDWARDS AFB	FV2805	93560	4,869	360,067	5,229	394,967	4,259	334,506	5,119	350,728
ELLSWORTH AFB	FV4690	57706	5,318	414,975	6,939	536,856	4,831	379,448	4,184	328,621
F E WARREN	FV4613	82009	29,475	1,814,125	30,300	1,872,741	32,145	1,930,941	25,978	1,638,694
FAIRCHILD AFB	FV4620	99001	6,627	507,777	6,721	510,555	6,963	535,107	6,196	477,668
GOODFELLOW AFB	FV3030	76905	1,616	128,821	2,141	178,171	1,410	107,941	1,298	100,350
GRAND FORKS AFB	FV4659	58204	2,491	193,789	3,216	253,814	2,692	207,547	1,564	120,005
GRISSOM ARB	FV4654	46914	3,676	257,089	5,032	361,529	3,317	216,760	2,678	192,977
HANSCOM AFB	FV2835	01731	2,383	182,413	3,559	261,589	2,144	165,479	1,446	120,172
HILL AFB	FV3365/FV2027	84056	9,777	646,667	18,663	1,112,235	6,107	474,002	4,561	353,765
HOLLOMAN AFB	FV4801	88330	22,329	1,216,397	20,613	1,268,609	23,182	991,686	23,191	1,388,895
HOMESTEAD ARB	FV6648	33039	1,962	138,891	2,052	142,481	1,073	86,846	2,760	187,347
HURLBURT FLD	FV5185	32544	45,858	3,326,582	49,454	3,617,514	47,496	3,449,356	40,625	2,912,877
JOINT BASE MDL	FV4484	08641	20,204	1,542,906	22,033	1,694,115	18,283	1,424,149	20,296	1,510,453
KEESLER AFB	FV3010	39534	4,913	385,196	7,952	623,070	3,347	258,680	3,440	273,839
KIRTLAND AFB	FV4469	87123	30,276	1,565,993	29,859	1,329,627	31,518	1,704,186	29,451	1,664,167
LACKLAND AFB	FV3047	78236	134,765	8,465,401	128,980	8,157,401	148,052	9,134,686	127,264	8,104,115
LANGLEY AFB	FV4800	23665	9,144	716,157	11,815	913,366	7,721	619,610	7,895	615,496
LAUGHLIN AFB	FV3099	78843	1,141	90,360	1,671	133,230	872	67,498	878	70,351
LITTLE ROCK AFB	FV4460	72099	8,743	672,499	13,282	1,037,049	6,121	497,634	6,825	482,814
LUKE AFB	FV4887	85309	5,054	378,521	6,442	490,064	4,515	334,427	4,206	311,071
MACDILL AFB	FV4814	33621	11,744	989,808	12,704	1,043,047	10,091	868,203	12,438	1,058,175
MALMSTROM AFB	FV4626	59402	13,688	953,058	13,852	972,769	13,934	965,087	13,278	921,319
MARCH ARB	FV4664	92508	4,136	321,931	6,072	486,786	3,542	265,691	2,795	213,316
MAXWELL AFB	FV3300	36112	5,491	509,389	6,370	594,713	5,083	473,731	5,020	459,722
MCCHORD FIELD	FV4479	98438	11,420	875,385	12,757	1,012,917	10,827	879,043	10,675	734,194
MCCONNELL AFB	FV4621	67210	8,814	682,203	11,069	867,252	8,530	632,739	6,843	546,619
MINN ST PAUL ARS	FV6633	55450	2,809	207,635	3,090	233,730	3,100	232,712	2,238	156,464
MINOT AFB	FV4528	58704	28,565	1,871,410	33,623	2,155,078	27,568	1,828,415	24,505	1,630,737
MOODY AFB	FV4830	31699	42,913	1,697,170	39,130	1,505,363	44,762	1,651,542	44,846	1,934,605
MOUNTAIN HOME AFB	FV4897	83648	11,487	713,199	13,847	1,075,345	5,897	430,621	14,717	633,630
NAS JRB CARSWELL AFB	FV6675	76127	2,298	172,935	3,191	243,874	1,292	92,538	2,412	182,393
NELLIS AFB	FV4852	89115	58,239	2,110,427	61,585	1,950,607	61,997	2,262,386	51,137	2,118,287
NIAGARA FALLS ARS	FV6670	14304	2,216	163,430	2,274	169,760	1,716	126,019	2,657	194,512
OFFUTT AFB	FV4600	68005	7,029	570,901	6,845	554,811	7,172	575,780	7,070	582,111
PATRICK AFB	FV6607/FV2520	32925	17,296	735,525	22,755	896,743	9,747	518,612	19,387	791,221
PITTSBURGH IAP- ARS	FV6712	15108	2,628	190,964	3,133	222,493	2,759	203,569	1,991	146,831
POPE AFB	FV4488	28308	23,902	1,893,100	19,704	1,443,625	26,892	2,185,973	25,108	2,049,701
RANDOLPH AFB	FV3089	78148	3,864	294,958	5,588	403,880	2,939	239,701	3,064	241,294
SCOTT AFB	FV4407	62225	6,683	517,302	8,036	620,596	6,225	482,233	5,787	449,077
SEYMOUR-JOHNSON AFB	FV4809	27531	9,393	636,083	12,302	784,973	7,827	523,370	8,051	599,906
SHAW AFB	FV4803	29152	6,144	443,293	10,300	687,449	2,747	209,201	5,385	433,230
SHEPPARD AFB	FV3020	76305	3,440	265,248	5,196	403,949	2,869	219,991	2,256	171,803
TINKER AFB	FV2037	73130	7,434	562,689	7,783	622,905	6,760	534,068	7,760	531,094
TRAVIS AFB	FV4427	94535	10,465	802,911	13,479	1,052,928	9,340	692,623	8,577	663,182
TYNDALL AFB	FV4819	32403	4,508	358,460	4,080	327,986	5,398	417,148	4,045	330,246
VANCE AFB	FV3029	73705	1,023	85,426	1,441	120,191	730	63,627	898	72,461
VANDENBERG AFB	FV4610	93437	4,699	356,332	5,055	386,365	5,174	381,818	3,869	300,813
WESTOVER ARB	FV6606	01022	1,717	133,744	2,183	165,024	1,387	108,723	1,579	127,485
WHITEMAN AFB	FV4625/FV6616	65305	8,260	591,549	6,207	425,260	9,541	697,970	9,031	651,416
WR-ALC ROBINS AFB	FV2067	31098	8,559	674,960	9,204	739,125	7,663	603,259	8,810	682,497
WRIGHT PATTERSON AFB	FV2300	45435	7,838	562,960	8,690	614,232	7,491	553,758	7,334	520,891
YOUNGSTOWN WARREN ARB	FV6656	44473	1,821	135,189	2,583	189,610	1,820	125,721	1,060	90,237
Total			815,908	51,895,781	901,046	57,307,117	788,434	50,005,880	758,242	48,374,345

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14. ABSTRACT
The purpose of this research was to explore the creation of an Air Force reverse logistics network to process Expended Small Arms Cartridge Casings (ESACC) after recent changes made by the Defense Logistics Agency ESACC Policy. Specifically, this paper explored ESACC market price, Air Force ESACC generation, use of automated equipment to process ESACCs, and Department of Defense Less than Truck Load transportation costs to create a revenue generating reverse logistics network for the Air Force. The research explored multiple models utilizing the Single Source Capacitated Facility Location Problem and how the solutions generated by those models can be used by the Air Force.

15. SUBJECT TERMS
Reverse Logistics, Single Source Capacitated Facility Location Problem, Less than Truckload, End of Life Policy

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