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**An Inventory and Safety Stock Analysis of Air Force Medical Service  
Pharmaceuticals**

THESIS

Blake M. Smith, Captain, USAF

AFIT-ENS-MS-15-M-133

**DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY**

***AIR FORCE INSTITUTE OF TECHNOLOGY***

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**Wright-Patterson Air Force Base, Ohio**

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**An Inventory and Safety Stock Analysis of Air Force Medical Service  
Pharmaceuticals**

THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Logistics Management

Blake M. Smith, BS

Captain, USAF

March 2015

**DISTRIBUTION STATEMENT A.**  
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AN INVENTORY AND SAFETY STOCK ANALYSIS OF AIR FORCE MEDICAL  
SERVICE PHARMACEUTICALS

Blake M. Smith, BS

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Member

### **Abstract**

A significant challenge facing the Air Force Medical Service (AFMS) Military Treatment Facilities (MTFs) is the perishability costs associated with its pharmaceutical stock. During a two year time period, the AFMS returned expired or nearly expired pharmaceuticals valued at over \$23,000,000. In response to the waste represented by pharmaceutical perishability cost, this thesis analyzes the historical inventory management decisions of 173 MTF/pharmaceutical combinations and proposes an alternative inventory control policy to reduce perishability costs. Based on the critical nature of pharmaceuticals and importance of generating high patient satisfaction, the proposed alternative inventory control system was required to be cognizant of the cost savings/service level trade-off. After applying a fundamental inventory management equation to historical patient demands, the calculated inventory control policy is evaluated against a recent nine month time period of patient demand in terms of potential cost savings and fill rates. At the conclusion of the study, it is determined that the use of the proposed inventory control policy would generate an effective perishability cost savings of approximately \$250,000 annually, as well as a one-time inventory reduction cost savings that exceeds \$1,700,000. In spite of this stock reduction, the studied MTF/pharmaceutical combinations would maintain a strong fill rate that exceeds 99.82%.

Dedicated to

*My wife for her love, support, and the sacrifices she has made!*

*My parents for giving me every opportunity possible!*

## **Acknowledgments**

I would like to extend my sincere gratitude to my research committee, Dr. William Cunningham and Lt Col Adam Reiman for their guidance and support throughout the research process. I would also like to thank Mr. Christopher Canales of the Air Force Medical Operations (AFMOA)/SGAL office for his assistance in developing the research topic and providing the data necessary to complete the thesis.

Blake Smith



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## I. Introduction

### Background

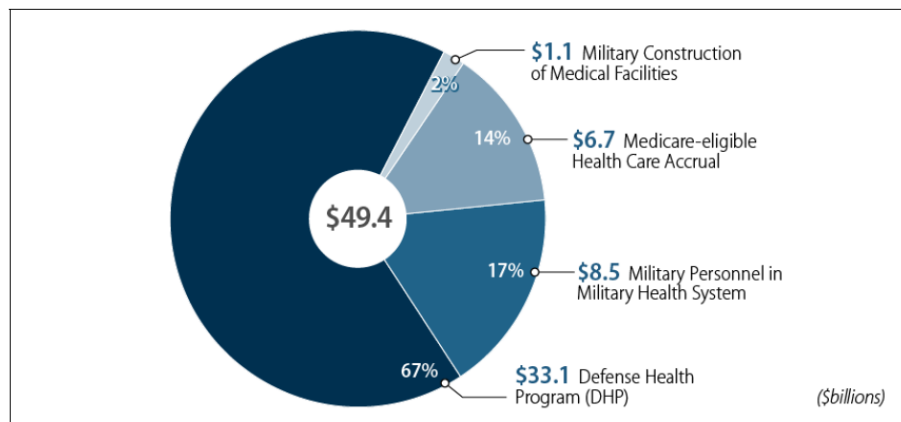
As the United States' (U.S.) debt position soars past eighteen trillion dollars ([www.usdebtclock.org](http://www.usdebtclock.org)), pressures continue to mount in favor of reduced federal spending. Based on this sentiment, the Future Year Defense Program (FYDP) budget has become a target of considerable scrutiny. This is primarily based on the fact that the Department of Defense (DoD) consumes the largest portion of the federal government's discretionary spending authority. Receiving the most scrutiny within the DoD budget is the unsustainable growth of personnel costs. The Secretary of Defense (SECDEF) weighed in on the issue during a speech that he delivered to the Center for Strategic and International Studies on November 5, 2013.

Without serious attempts to achieve significant savings in this area [military personnel costs] — which consumes roughly half of the DoD budget and is increasing every year — we risk becoming an unbalanced force ... one that is well-compensated, but poorly trained and equipped, with limited readiness and capability.

Chuck Hagel,  
Secretary of Defense (2013)

Military personnel costs accounted for approximately 130 billion dollars of the overall 512 billion dollar fiscal year (FY) 2014 DoD budget (Office of Management and Budget, 2013). While military personnel costs are comprised of significant budgetary line items such as base pay, allowances, and retired pay accrual, it is the rapid escalation of defense related healthcare costs that has led many to conclude that current policies are unsustainable (Rugy, 2014). Figure 1 displays the breakdown of the 49.4 billion dollar FY 2014 budget associated with military healthcare costs, accounting for approximately

9.39 percent of the overall defense budget. This current portion of the overall defense budget is up from approximately 6 percent in FY 2000.



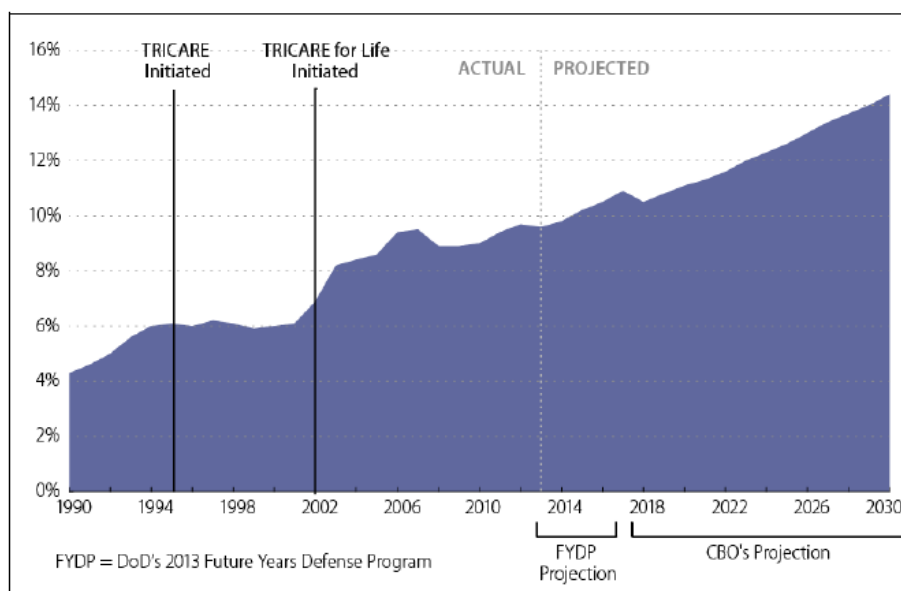
Source: Department of Defense FY2014 Budget Request Overview. Adapted by CRS Graphics.

**Figure 1: FY 2014 Unified Medical Budget Request (\$billions)**

The most alarming aspect of the defense healthcare cost is that it is projected to expand at a rate much higher than other defense related costs. The Congressional Budget Office (CBO) projects that the defense healthcare cost will skyrocket to 95 billion dollars by FY 2030, accounting for over 14% of the nation’s projected defense requirement of the same year (Jansen, 2014:17). Figure 2 displays a graphical representation of the CBOs projection of defense related healthcare costs consuming larger portions of the overall defense budget in future years.

An additional challenge facing the DoD is the Budget Control Act of 2011, which constrains defense related spending through the year 2021. In this fiscally constrained environment, the continuation of rapidly escalating healthcare costs could force the DoD to make difficult tradeoff decisions and reduce spending in areas such as force structure, military readiness, and weapons modernization (Congressional Budget Office, 2014). These types of actions have become reality with the President’s proposed 2015 defense budget calling for a reduction in force structure across all military services along with

the retirement and cancellation of other weapon systems (Simeone, 2014). Current strategies to control the DoD’s rising healthcare costs have largely focused on proposals that shift financial burdens to military personnel by raising enrollment fees, deductibles, or copayments (Rugy, 2014). While these measures may prove to be necessary in sustaining future military capabilities, the DoD must first perform a fundamental review of its healthcare delivery methods in search of opportunities that increase efficiencies while maintaining a high level of service for its beneficiaries.



Source: Carla Tighe Murray, Approaches to Reduce Federal Spending on the Defense Health System, Congressional Budget Office, July 31, 2013, p. 2, <http://www.cbo.gov/publication/44393>.

**Figure 2: Future Year Projection of Healthcare Costs as a Percentage of the DoD Budget**

### Problem Statement

One healthcare delivery method that is fitting of such a fundamental review is the distribution of pharmaceuticals. Pharmaceuticals are a primary contributor to the escalating healthcare costs shouldered by the DoD. The DoD’s pharmaceutical costs have expanded from approximately three billion dollars in 2002 to approximately 6.8 billion dollars in 2011, outpacing the overall pharmaceutical sales rate in the U.S. by



nearly double. To put this into perspective, the DoD spent more resources on pharmaceuticals than it did on Black Hawk helicopters, Abrams tanks, Hercules C-130 cargo planes and Patriot missiles—combined (Schwartz & McDonald, 2013).

The DoD provides pharmaceutical benefits to its eligible beneficiaries by means of three distinct delivery methods. These three methods include local retail pharmacies, mail-order service, and DoD Medical Treatment Facility (MTF) distribution. Studies have shown that pharmaceuticals delivered through the retail pharmacy method cost the DoD more than when the same pharmaceuticals are delivered through the mail-order and MTF distribution methods (Rand Corporation, 2005). The primary reason that the MTF distribution method is most cost effective on a per prescription basis is that it utilizes a prime vendor for all pharmaceutical supplies. On January 25, 2005, the Defense Logistics Agency (DLA) awarded the Pharmaceutical Prime Vendor (PPV) Generation III contract to AmerisourceBergen Drug Corporation for TRICARE regions North and South and to Cardinal Health Inc. for TRICARE West (Defense Logistics Agency, 2014).

The PPV Generation III contract provides multiple benefits to the MTFs of all military branches. One of the key benefits of the contract is the ten year pricing agreement with declining distribution fees as the contract ages. It is the combined purchasing power of all DoD MTFs across the Contiguous United States (CONUS) and the pricing agreement included in the PPV Generation III contract that enables the MTF pharmacies to dispense prescriptions to TRICARE beneficiaries in a cheaper manner than their retail counterparts. Additionally, the PPV Generation III contract provides contractual fill rates that range between 95 and 98 percent and include a one business

day delivery lead time. Although the PPVs are contractually responsible for filling 95 to 98 percent of MTF's daily pharmaceutical requirements, their historical performance has far exceeded this obligation. A secondary "back-up" contract is also in place to be utilized in the event that the PPV cannot fill an MTF requirement (Defense Logistics Agency, 2014). The high fill rates and shortened delivery lead times afforded by the PPV Generation III contract should be leveraged by the MTFs to reduce their respective pharmaceutical inventories.

Despite this fact, there is evidence to suggest that Air Force Medical Service (AFMS) MTFs have not seized this opportunity to reduce pharmaceutical inventories. Per the Air Force Medical Operations Agency (AFMOA)/SGAL office, the aggregated value of pharmaceutical inventory positions across all Air Force MTFs is in excess of 134 million dollars. The same AFMOA/SGAL office estimates that the aggregated inventory position across all AFMS MTFs should be closer to a value of 32 million dollars. Perhaps the most alarming evidence suggesting that the AFMS currently holds too much pharmaceutical inventory is based on the fact that it returned a significant amount of pharmaceuticals that were either past its expiration date of clinical effectiveness or nearing the expiration date. Over the two year time period of September 2012 through September 2014, these returns were valued at over 23 million dollars. While the PPV Generation III contract provides a mechanism for MTFs to recoup approximately 40 percent of the sale price for the return of pharmaceuticals with a remaining lifespan of clinical effectiveness, the pharmaceuticals returned through the reverse distribution vendor represent waste within the process.

## **Research Objectives/Questions**

Given the problem, the purpose of this study is to identify an ordering policy that would reduce the AFMS' pharmaceutical inventory position, while maintaining a high level of patient prescription fill rates. The overarching objective is to demonstrate a potential for cost savings that can be achieved through a sound ordering control policy and the execution of inventory management procedures applied to the AFMS' pharmaceutical supplies. In the pursuit of this objective, three research questions will be addressed:

1. What cost savings can the AFMS realize in terms of reducing the amount of expired or near expired pharmaceutical returns, given the application of an inventory control system that utilizes adjusted order-up-to stock level quantities?
2. What cost savings can the AFMS realize in terms of reducing on-hand pharmaceutical stock, given the application of an inventory control system that utilizes adjusted order-up-to stock level quantities?
3. What impact will the proposed inventory control system have on pharmaceutical fill rates?

## **Methodology**

This study uses a multiple phased methodology approach to address its three research questions. As with most research efforts, the initial phase of this study consisted of collecting pertinent data sets. The first set of data collected was that of the AFMS pharmaceutical returns over a two year time period. Along with providing the motivation for the study altogether, the pharmaceutical returns data was used to focus the study on the inventories of 32 distinct pharmaceuticals across all CONUS MTFs. Because not all CONUS MTFs recorded returns of the 32 pharmaceuticals, the study performed inventory analysis that culminated over 173 MTF/pharmaceutical

combinations. Additionally, patient pharmaceutical demand records, PPV sourcing records, and the Defense Medical Logistics Standard Support (DMLSS) Customer Area Inventory Management (CAIM) suggested levels were collected for use in subsequent phases of the methodology.

The next phase of the methodology consists of constructing an estimate of the historical inventory positions for the respective MTF/pharmaceutical combinations. This estimation is a necessary step based on the actual inventory positions not being available for use in this study. Therefore, an estimated daily timeline of historical inventory positions for the respective MTF/pharmaceutical combinations were constructed by using the daily patient demand records, PPV sourcing records, and the number of units returned to the reverse logistics vendor.

The primary challenge with the reconstruction of the daily inventory positions was the absence of a starting inventory position on the first day of analysis (1/1/2012). In lieu of the actual starting inventory position, the study used the DMLSS CAIM suggested level for its starting inventory position. The one exception to using the CAIM suggested level takes place if that level allows the inventory position to fall below zero, signifying a stockout. Because the patient demand data is actually representative of the prescriptions filled by the MTF pharmacies, stockouts were not permitted in the recreation of the historical inventory positions. In these cases, the starting inventory position was raised to the minimum level that ensured zero stockouts occurred in the historical reconstruction of the inventory positions.

The third phase of the methodology consists of calculating an alternative order-up-to stock level for each of the respective MTF/pharmaceutical combinations. A basic

inventory management equation is applied to the 1/1/2012 through 12/31/2013 patient demand data to determine an appropriate order-up-to stock level. Upon the completion of these calculations, the alternative order-up-to stock levels are evaluated with respect to the patient demand data under the time period of 1/1/2014 through 9/19/2014. The alternative order-up-to stock levels are evaluated in terms of cost savings and pharmaceutical fill rates, thereby providing answers to the study's three research questions.

### **Assumptions**

The primary assumption of the study is that the collected data is accurate and representative of the actual pharmaceutical inventory transactions that took place over the three year span. This is a reasonable claim, based on the fact that the data sets were collected directly from their official record keeping systems (i.e., DMLSS and the Military Health System Management Analysis and Reporting Tool). The study also makes three additional assumptions in an effort to reduce complexity within the inventory analysis.

The first of these assumptions is that the research effort will use a fixed value of six months to represent the individual pharmaceutical's lifespan of clinical effectiveness in the inventory analysis. The six month value was chosen based on the fact that it represents the shortest acceptable lifespan of a newly supplied pharmaceutical as prescribed in the PPV Generation III contract. This life expectancy assumption undertakes a conservative approach, based on it representing the worst case scenario.

The second assumption found within the study is that it treats the delivery lead time of all pharmaceuticals as a deterministic value of one business day. This assumption was based on the PPV Generation III contract parameters and the vendor's historical demonstration of meeting this requirement on nearly all occasions. The final assumption of the study is that the inventory model will assume a First-In First-Out (FIFO) distribution policy. This is common practice of all pharmacies, where the newest pharmaceuticals are placed behind older pharmaceuticals in the pharmacy shelving.

### **Limitations**

Based on time and data constraints, this study possesses three limitations that must be considered. The first limitation is that the study will focus on only the pharmaceutical inventory management practices of Air Force (AF) MTFs within the CONUS. While many of the principles introduced in this study are applicable to the MTFs of other military services and MTFs Outside [the] Contiguous United States (OCONUS), the results found in this study cannot be generalized to those MTFs.

The second limitation found within the study is that analysis could not feasibly be performed on the 15,098 distinct pharmaceuticals that were returned by AFMS MTFs over the two year period. While the study performs analysis on only 32 of these pharmaceuticals, an attempt to reduce this limitation was made by focusing on the pharmaceuticals that exhibited the greatest portion of returns as measured by dollar value.

The third limitation found within the study is that patient demand, PPV sourcing, and returns data is aggregated across all pharmacies operating under the authority of a

MTF. This is a potential limitation to the study based on the common practice of most MTFs operating a main pharmacy within the primary clinic facility, while also operating a “refill” pharmacy that is typically located in an area near the Base Exchange or Commissary. While this limitation has the potential to affect the savings and fill rate calculations, the magnitude of the loss in precision should be minimal.

## **Implications**

The Department of Defense is facing a legitimate challenge in the form of rising healthcare costs. As referenced before in the background section of this chapter, the CBO projects that the defense healthcare cost will skyrocket to \$95 billion by the year 2030, accounting for over 14% of the nation’s projected defense requirement in the same year (Jansen, 2014). As healthcare costs are projected to surge within the Department of Defense budget, civilian and military leaders will be forced to choose between a potential reduction in healthcare benefits for beneficiaries or a reduction in war fighting capabilities (personnel and weapon systems). The only solution to avoiding this unenviable position is to reduce or at the very least slow the growth of military healthcare costs.

While this study in pharmaceutical supply operations does not intend to present the grand illusion of solving the challenge of rising healthcare costs in one fell swoop, it does provide a starting point from which to begin. Along with the modest cost reduction that the proposed research study intends to accomplish, it will also provide momentum for additional research within the Air Force Medical Service to be initiated.

## **Thesis Organization**

This thesis is comprised of five chapters. Chapter 2 provides a summary of extant literature that is relevant to the research questions posed in Chapter 1. The summary of relevant literature is further categorized into the inventory management of non-perishable items with deterministic demand, non-perishable items with stochastic demand, non-specific perishable items, perishable blood donations, and concludes with the inventory management of perishable pharmaceuticals. Chapter 3 summarizes the methodology used in this research effort. The primary phases of the methodology include data collection, estimation of historical inventory positions, the calculation of an alternative order-up-to stock level, and concludes with an evaluation of the alternative order-up-to stock level. Chapter 4 presents the results and analysis of the performed methodology. Chapter 5 provides a summary of the study by answering the research questions and concludes the thesis with recommendations for action and future research.



## II. Literature Review

### Chapter Overview

The inventory management discipline has been studied extensively by operations research analysts and practitioners alike. The primary objective of the inventory management discipline is for an organization to determine inventory policies for individual products that result in the maximum net benefit. In other words, the organization seeks the optimal levels of inventory that allows for the fulfillment of customer demand while also limiting the costs associated with holding excess inventory. The study of inventory management can be separated into two categories; products exhibiting indefinite or long term life expectancies and products possessing fixed finite life expectancies. The products possessing fixed finite life expectancies are commonly referred to in the extant literature as perishable items. Examples of perishable items include amongst others: grocery items, seasonal fashion items, blood donations, and pharmaceuticals.

Despite the perishability factor of pharmaceuticals, this literature review will begin by briefly introducing the contributions of early studies focusing on the derivation of optimal inventory management policies for non-perishable products. The decision to include non-perishable inventory management studies stems from the fact that these studies set the foundation for the much more complex studies of perishable inventory. The literature review of non-perishable inventory management studies will be separated into those with a deterministic product demand rate and those with a stochastic product demand rate.

Upon the completion of the non-perishable inventory management section, the remaining focus of this chapter will be to review the extant literature that is associated with the inventory management of perishable products. The remaining review of extant literature on the inventory management of perishable products will be separated into three sections. The first section will introduce studies that pertain to the general discipline of perishable inventory management. This section will include the fundamental studies that provided the foundation for expanded studies that specifically address the inventory management policies of perishable items related to the effective and efficient delivery of healthcare.

The second section of the remaining literature review will introduce the extant research that focuses on the management of blood donation inventories. Soon after the fundamental ground work for the discipline of perishable inventory management was set, the inventory operations of blood banks became a popular topic amongst operations research analyst. One explanation for the popularity of the blood bank research stems from the high stakes that are associated with whole blood availability for transfusions and other medical procedures. The literature review will conclude with an introduction to the extant research conducted on the inventory management practices of pharmaceuticals. While studies on pharmaceuticals have not yet reached the prevalence attained by blood bank research, it is growing in response to the significance that pharmaceuticals play in the overall cost of healthcare delivery.

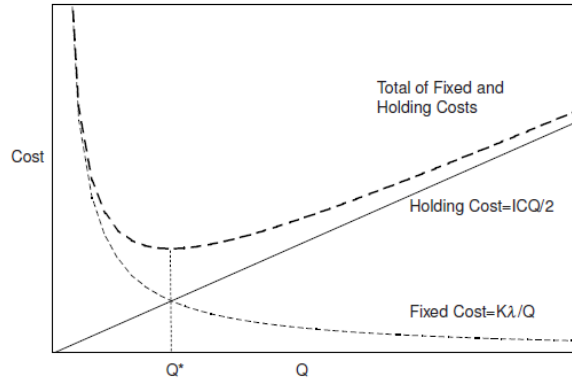
## Inventory Management of Non-Perishable Items with Deterministic Demand

Perhaps the most fundamental paradigm in the discipline of inventory management ensued with Ford Whitman Harris' derivation of the Economic Order Quantity (EOQ) calculation. In his article, titled *How Many Parts to Make At Once*, Ford Whitman Harris describes an economic quantity calculation for determining the optimal production lot size for the manufacturing industry (Harris, 1913). While there is some debate over who was the first to expand Harris' original work on the EOQ, it was quickly modified and applied to the inventory control problem of determining the optimal order quantity for an individual product (Erlenkotter, 1990). Harris' basic EOQ model requires underlying assumptions to be made upon the circumstances of the inventory item being analyzed (Silver, Pyke, & Peterson, 1998). Table 1 displays the eight underlying assumptions of the EOQ model below:

**Table 1: Underlying Assumptions of the EOQ Model**

EOQ Assumptions
● The product demand rate is constant and deterministic
● There are no minimum or maximum restrictions on the size of an order
● The unit variable cost is fixed
● The cost factors do not change with time
● No shortages/backorders are permitted
● The delivery lead time for a product is fixed
● The entire order quantity is delivered at the same time
● Substitutions of products are not permitted

Given these assumptions, the basic EOQ model determines the order quantity that minimizes the total cost by assessing the tradeoff between a fixed ordering cost and a holding cost represented as a percentage of the unit variable cost in stock (Muckstadt & Sapra, 2010). Figure 3 displays the fixed and holding costs as functions of the optimal order quantity ( $Q^*$ ).



**Figure 3: Fixed and Holding Costs Functions of the Order Quantity (Muckstadt & Sapro, 2010)**

The basic EOQ formula is then given as:

$$EOQ = \sqrt{\frac{2K\lambda}{IC}} \quad (1)$$

Where

$K$  = Fixed Order Cost

$\lambda$  = Annual Demand Rate of the Product

$I$  = Holding Cost (% of unit variable cost)

$C$  = Unit Variable Cost

With the optimal order quantity calculated with respect to the underlying assumptions, the final piece of the inventory control policy needed is the determination of the reorder point. Since the on hand inventory position of an item is assumed to be zero upon replenishment, the inventory level upon which a replenishment order is requested is equal to the demand of the product ( $\lambda$ ) during the lead time ( $\tau$ ) of the replenishment. Therefore, the reorder point ( $r$ ) for the basic EOQ model is equal to  $\lambda\tau$ .

## **Inventory Management of Non-Perishable Items with Stochastic Demand**

While the EOQ is regarded as the fundamental paradigm for the inventory management discipline, it is often criticized for its restrictive underlying assumptions. The main assumption of the basic EOQ model that does not correspond with reality is the assumption of the product demand exhibiting a constant and deterministic rate. In reality, the product demand rate is stochastic. With a stochastic product demand rate, the organization must forecast the product demand rate while also accounting for the variability of the forecast by including a safety stock level to buffer against the threat of a product stockout.

The two most common approaches to determining a safety stock level are through a basis of minimizing cost as well as a basis of meeting a predetermined customer service level (Silver, Pyke, & Peterson, 1998). The approach based on minimizing cost explicitly or implicitly assigns a cost to a stockout occurrence and then attempts to minimize the total cost by assessing the tradeoff between the stockout cost and the holding cost of excess inventory. The approach based on meeting a predetermined customer service level uses statistical analysis of the product demand lead time to determine the appropriate safety stock level that is necessary to attain or exceed the service level constraint.

Facing the reality of a stochastic product demand rate, the majority of non-perishable inventory management literature focuses on the derivation of optimal or near-optimal stock levels with regards to three common inventory control policies (Silver, Pyke, & Peterson, 1998). The first inventory control policy is referred to as the Order-Point, Order-Quantity ( $s, Q$ ) policy. This inventory control policy features a fixed

quantity (Q) being ordered whenever the inventory position of an individual product drops below the reorder point (s). The second policy is referred to as the Order-Point, Order-Up-To level (s, S) policy. Similar to the previous (s, Q) inventory control policy, the (s, S) policy places a replenishment order when the individual products inventory position drops below the reorder point (s). The difference between the two policies is that the (s, S) policy places a replenishment order with a variable quantity that equals the difference between the order-up-to level and the net inventory position.

The third and final inventory control policy that is commonly found in the extant literature is referred to as the Periodic-Review, Order-Up-To-Level (R, S) policy. The (R, S) policy has a predetermined time interval for reviewing the inventory position of an individual product (i.e., once a day, once a week, etc.). During this periodic review of the inventory position, a replenishment order is made in the amount equal to the difference between the Order-Up-To-Level (S) and the individual product's net inventory position. This is essentially the inventory control policy used by AFMS pharmacies.

### **Inventory Management of Non-Specific Perishable Items**

One of the fundamental contributors to the research of perishable inventory management practices is Dr. Steven Nahmias of Santa Clara University. In one of his earliest works, entitled *Optimal Ordering Policies for Perishable Inventory—II*, Nahmias (1975) develops a single period model for a single perishable product where an assumption is made that replenishment orders are placed at the beginning of each period and are received instantaneously (no positive lead time). In pursuit of minimizing costs

associated with various ordering policies, the overall cost of the inventory policy is charged linearly for ordering, holding, stockout, and expiration costs. When Nahmias attempts to derive the optimal ordering policies of a single perishable product in a multi-period time horizon, he finds that with the exception of products with very short life expectancies, the computations are not realizable.

Nahmias (1982) followed this study by completing a summary and review of the extant research in the field of perishable inventory theory up until the 1982 date of publishing. Nahmias begins by distinguishing the attribute of inventory perishability as either fixed lifetime or random lifetime. Since the expiration date associated with all pharmaceuticals represents a definitive date of clinical effectiveness, the author's review of fixed life perishability is most pertinent to the AFMS pharmaceutical research effort. Nahmias' study further categorizes fixed life perishability into deterministic and stochastic product demands. Nahmias begins by reviewing research applying a periodic review with known demand, as found in a dissertation effort by A. F. Veinott (1960). Unfortunately, these assumptions are not practical for application based on the occurrence of demand changing over time in reality.

Nahmias proceeds to introduce the research that had been conducted on perishable products with stochastic demand. Echoing a conclusion from his previous work, he states that when demand is stochastic and the life expectancy of the product exceeds one period, the computation of optimal ordering policies is extremely difficult. Nahmias acknowledges the first researcher to tackle a two period life expectancy problem was G. J. Van Zyl. Van Zyl (1964) modeled the two period life expectancy product with respect to the proportional costs of ordering and stockouts. Similarly,

Nahmias and Pierskalla (1973) modeled the two period life expectancy product with respect to the costs of stockouts and product expiration.

Expansion of the research into inventory optimization models for perishable products exceeding a fixed life expectancy that was greater than two periods was developed simultaneously and independently by Fries (1975) and Nahmias (1975). Their research showed that an increase of initial stock of inventory of any age by one unit will decrease the optimal order quantity by less than a single unit. Despite this finding, the researchers found that the computational time of using either model for product life expectancies greater than or equal to three periods is difficult and impractical for a real problem.

Nahmias later teamed up with Charles P. Schmidt (1985) to study the modeling of  $(S-1, S)$  policies for a single perishable item with a fixed and known life expectancy. A  $(S-1, S)$  inventory control policy suggests that an order is placed for exactly one unit at each occurrence of a product demand and at each occurrence of a product expiration in the case of perishable items. The significance of this study is that it was the first of its kind to incorporate a positive lead time for product replenishment. Using this model, Schmidt & Nahmias display a sensitivity analysis that demonstrates the impacts of various levels of product life expectancy and replenishment lead times on the optimal value of  $S$ , as well as the expected annual cost for the indicated parameters. The early works by Nahmias and other pioneers in the study of perishable inventory management laid the groundwork for others to expand upon their work and focus on specific assumptions and control models of perishable inventory.



B. C. Giri & K. S. Chaudhuri (1998) pursue an EOQ-type inventory model approach with a demand rate that is dependent on the on-hand inventory stock level of the specified perishable product. This is based on the Levin et al. (1972) research that suggested "at times, the presence of inventory has a motivational effect on the people around it. It is a common belief that large piles of goods displayed in a supermarket will lead the customer to buy more". The primary significance of the Giri & Chaudhuri article is that they treat the holding cost parameter of the EOQ model as a nonlinear function of the length of time for which the item is held in stock.

Liming Liu & Zhaotong Lian (1999) expand the body of knowledge by analyzing a  $(s, S)$  continuous review perishable inventory model with a general renewal demand process and instantaneous replenishment of ordered stock. Inspired by a lack of extant literature addressing the optimization of a continuous review perishable inventory model, the Liu & Lian use a Markov renewal approach to obtain closed-form solutions for the steady state probability distribution of the inventory level. Additionally, the Liu & Lian use a closed-form expected cost function to study the impact of various parameters. The Liu & Lian study concludes that because the distribution of the objective function is not affected by the coefficient of variation of the demand process, it is reasonable to believe that the  $(s, S)$  policy is the optimal model for general renewal demand processes.

Hideki Katagiri & Hiroaki Ishii (2002) address the ambiguity of accurately estimating the cost of stockouts and expiration cost as constant values when considering perishable inventory problems. The researchers derived a single-period inventory model of perishable products using "fuzzy numbers" for the stockout and expiration costs. The

authors introduce the fuzzy max order, derived by N. Furukawa (1994), to define non-dominated ordering quantities for maximization of expected profits as solutions to the perishable inventory problem.

Fredrik Olsson & Patrik Tydesjö (2010) expand upon the Schmidt and Nahmias (1985) research to consider a single perishable product with a Poisson demand, fixed life expectancy, and fixed replenishment lead time. Fredrik Olsson & Patrik Tydesjö apply a (S-1, S) policy for stock replenishments. The authors consider three different cases where service level requirements are represented by stockout costs per unit, a service level constraint, and stockout costs per unit and time. The authors conclude the study with a sensitivity analysis of the three cases using various parameter inputs.

### **Inventory Management of Perishable Blood Donations**

One of the earliest applications of the perishable inventory management research topic was on the management of whole blood units within local and regional blood banks. Donated blood is a valuable commodity for medical treatment of conditions requiring transfusions. The American Red Cross estimates that someone in the U.S. requires blood every 2 seconds of the day ([www.redcrossblood.org](http://www.redcrossblood.org)). The complexity surrounding the management of whole blood units is the requirement of needing a robust supply of the blood units on hand to respond to medical emergencies along with the constraint of its perishability. Blood bank managers are faced with the daunting task of ensuring the availability of all blood type units for use in life saving procedures, while also attempting to limit the spoilage rate of such a valuable and limited resource. The

review below will introduce a sample of research that was conducted in search of improving the effectiveness and efficiency of blood inventory management.

Gregory Prastacos (1984) provides a comprehensive overview of the theory and practice of blood inventory management. One of the primary research efforts reviewed by Prastacos was conducted by J.B. Jennings. Jennings (1968) used a simulation to evaluate blood bank performance and derive trade-off curves displaying the events of expiration vs. stockouts as functions of the inventory levels. Prastacos suggests that the trade-off decisions between stockouts and expiration rates typically differ amongst the various blood types. Because the demand rate of rarer blood types must be stocked proportionally higher than common blood types to achieve the same stockout rates, they result in higher expiration rates.

A study of a large hospital in Philadelphia agreed with this notion as their expiration rates of rare blood types were dramatically higher than common blood types (Prastacos, 1984). The author suggests that this finding justifies the common practice of some hospitals not to stock the rare types. This generalization can be applied to the process of pharmaceutical formulary management. In order to limit the degree of pharmaceutical expiration rates, the medical staffs of healthcare facilities should be selective in their decisions to add new pharmaceuticals to the formulary. Additionally, medical staffs should conduct periodic reviews of their medical facilities' formulary to determine if any currently stocked pharmaceuticals should be removed from the formulary with respect to a declining future patient demand.

Dan Chazan & Shmuel Gal (1977) approach the blood inventory management quandary by using a Markovian model to compute the upper and lower bounds of the

average number of whole blood units exceeding its useful life expectancy versus a total number of inventory units in stock. The Markovian model was chosen to answer the research question of determining how much inventory could be held, and therefore reduce the risk of stockouts, without significantly increasing the number of blood units being discarded based on it exceeding its useful life expectancy.

David Perry (1997) provides a unique approach by using a double band control policy to model the blood bank perishability problem. With the number of items arriving during the age of the oldest item representing the model's stock level, the stock level of whole blood units is assumed to fluctuate as an alternating two-sided regulated Brownian motion between the barriers of expiration (represented by a value of 0) and stockout (represented by a value of 1). The model also assumes that the decision maker of the blood bank is able exercise control on the rates of arrival and demand. Therefore, the model includes two switchover levels that are positioned between the values of 0 and 1 ( $0 \leq a < b \leq 1$ ). When the stock levels reach the determined levels of a or b, the model assumes that the manager of the blood bank implements the appropriate measures to alter the arrival or demand of the blood units.

### **Inventory Management of Perishable Pharmaceuticals**

While there is currently not a significant amount of extant literature dedicated to the management of pharmaceutical inventories, it is a research topic that has recently been pondered by a growing number of operations research analysts. Although the majority of pharmaceuticals possess a longer fixed life expectancy than that of whole blood units, the inventory management of both products share the difficult tradeoff

decision between the requirements for maintaining a robust on hand inventory to meet patient demand with the conflicting constraint of limiting the waste associated with product expiration. The trade-off decision between costs and the level of required service is more complex and difficult to manage in the health care setting than it is in the manufacturing industry.

While the impact of stockouts in the manufacturing industry can be significant through the threat of lost sales, a stockout of critical pharmaceuticals and whole blood units can be harmful to the wellbeing of a patient in need. Although stockouts of blood units typically pose a more immediate threat to the health of patients in need, the impact of understocking pharmaceuticals can lead to increased dissatisfaction of physicians and a declining operational performance of the overall health care facility (Vries, 2011). J. Vries states that a proper balance between service metrics and costs is without a doubt the main logistical challenge that hospitals are faced with.

Another complexity that the inventory management of blood units and pharmaceuticals share stems from the fact that they both possess product demand rates that exhibit non-stationary behavior. There are three factors that cause patient demand of pharmaceuticals to be non-stationary. These factors include the change in patient condition dynamics, seasonalities, and the shifting of dosing requirements triggered by changes in patient characteristics such as age, weight, and blood pressure. Additionally, pharmaceutical demand is a function of the patient population mix from which the health care facility services. Despite the non-stationary behavior of pharmaceutical demand rates, early research on the topic of pharmaceutical inventory management treated the

demand rates as stationary and therefore possesses a lessened degree of validity (Vita-Parrish & Ivy, 2013).

Vita-Parrish & Ivy (2013) provide a detailed summary of three unique studies that treated the pharmaceutical demand rate as stationary. Little & Coughlan (2008) developed a stock level optimization model that accounted for storage space constraints, item criticality, and delivery frequency. One of the primary findings by Little & Coughlan was that the same patient service levels can be achieved by receiving replenishment deliveries on a daily basis with low space usage compared to the receipt of replenishment deliveries every three to five days with a high space usage. Claudia Rosales (2011) compared out-of-cycle and continuous review (s, S) replenishment policies of pharmaceuticals. Rosales' study concluded that a hybrid policy composed of the primary (s, S) policy and an out-of-cycle replenishment of a fixed order if stock positions reached a specified threshold was optimal. Derrek Descioli (2005) studied the performance of various inventory control policies within automated point-of-use systems under the condition of intermittent demand rates. The intermittent demand rates used in Descioli's model was a progressive step towards a dynamic demand model that incorporates non-stationary demand.

Anita Vila-Parrish, Julie Ivy, & Russell King (2008) were the first credited researchers to approach the inventory management of pharmaceuticals topic with a non-stationary demand rate. Vila-Parrish, Ivy, & King used a simulation based approach to model the inventory and ordering policies of an inpatient hospital pharmacy, where the model defines the patient demand of the individual pharmaceuticals as a function of the patient's condition. The study includes simulations of stationary and non-stationary

demand rates for comparison. The first policy, termed the "Fixed Policy", forecasts patient demand of pharmaceuticals based solely on historical demand. The second policy, termed "Adaptive Policy" uses the number and type of patient admitted to the inpatient facility. The results of the simulation show that the "Adaptive Policy" resulted in a lower total cost when compared to the "Fixed Policy" within the defined experiment set.

Vila-Parrish et al. (2012) expanded their previous study by modeling two stages of inventory with a production stage. The two separate stages of inventory come in the forms of raw materials and finished goods (e.g. intravenous medications), where the production stage transforms the raw materials into the finished goods. While deterministic, the life expectancy of a pharmaceutical is dependent upon its respective inventory stage. For example, the raw materials have a shelf life of up to one year while the finished goods have an unrefrigerated shelf life of less than one day. While the two stage inventory model expanded the body of knowledge concerning the pharmaceutical inventory management practices, it does not apply to this study based on its focus of pharmaceuticals remaining in just one inventory stage (raw materials).

## **Summary**

Chapter 2 provided a review of the relevant literature pertaining to the research pursuit of determining inventory control policies that provides the optimal mix between the minimization of inventory cost and the on hand availability of product for potential customer demand. The literature review was segregated into research studies performed on the inventory management principles of non-perishable products and perishable

products. Despite the fact that pharmaceuticals represent the later, the decision to include a review of non-perishable products was made based on the foundation it provided for the more complex study of perishable products. The review of inventory management principles pertaining to perishable products was further segregated into an overview of fundamental studies focusing on the generalities of perishable items followed by the extant research conducted on the inventory management of donated blood units and pharmaceuticals. While the stringent assumptions imposed on the models reviewed in Chapter 2 do not lend to complete applicability in this particular study, it provides a foundation from which the methodology will be based. Chapter 3 will detail the methodology used to evaluate the research questions posed in Chapter 1.



### **III. Methodology**

#### **Overview**

The purpose of this chapter is to present the inventory management methodology used in this study. The chapter begins by describing the data sets that were required to perform the inventory management methodology, as well as the process used for collection. Following this, the chapter will outline the steps taken to estimate the historical inventory positions of the chosen MTF/pharmaceutical combinations, compute alternative stock levels, and finally to evaluate the results of the alternative stock levels in terms of cost savings and fill rates.

#### **Data Collection**

The basic inventory management methodology used in this study required four distinct sets of data. Serving as the primary motivation for the study, the first set of data collected in the effort represented the identification of expired or nearly expired pharmaceuticals that were turned in by AFMS MTFs during the time period of September 2012 through September 2014. This data set, provided by the AFMOA/SGAL office, identified the turn-in of 15,098 unique pharmaceuticals with a replacement value of \$23,168,655.02. Because analysis of 15,098 individual pharmaceuticals at 81 dispensing locations was unfeasible given the time constraint for the study, a decision was made to narrow the scope of the study to a more manageable task.

As a result, a focus was placed on the top 59 pharmaceuticals accounting for the largest turn-in values amongst CONUS MTFs. Out of the top 59 pharmaceuticals

identified, 27 pharmaceuticals were further eliminated from the scope of the study based on War Reserve Material requirements, a discontinuance of patient demand during 2014, and other disqualifying factors such as the atypical procurement process of influenza vaccinations. Table 2 displays the 32 pharmaceuticals that were ultimately chosen for inventory analysis. The study performed inventory analysis on the 32 identified pharmaceuticals at up to ten MTFs, accounting for the largest portions of the turn-in value. For example, the top 10 out of 17 MTFs returning Premarin 1.25 mg tablets were analyzed, whereas all 5 of 5 MTFs returning the Combivent 4 g Inhaler were analyzed.

**Table 2: Pharmaceuticals Chosen for Inventory Analysis**

Pharmaceuticals	
● Abilify 30 mg Tablet	● Levitra 10 mg Tablet
● Acetasol HC Ear Drops	● Mefloquine 250 mg
● Advair 250-50 Diskus	● Nexium DR 40 mg Tablet
● Agrylin 0.5 mg Capsule	● Pancreaze DR 16,800 UU Capsule
● Avonex 30 mcgs	● Premarin 0.3 mg Tablet
● Celebrex 100 mg Capsule	● Premarin 0.625 mg Tablet
● Celebrex 200 mg Capsule	● Premarin 1.25 mg Tablet
● Combivent Respimat Inhaler 4 g	● Prograf 5 mg Capsule
● Epipen 2-pack 0.3 mg Auto-Injector	● Sandostatin Lar 30 mg
● Fosamax Plus D 70 mg--2,800 IU UU	● Spiriva 18 mcg CP-Handihaler
● Fosamax Plus D 70 mg--5,600 IU UU	● Tamiflu 75 mg
● Gleevec 100 mg Tablet	● Tobradex Eye Drops 5 ml
● Gleevec 400 mg Tablet	● Votrient 30 mg
● Glucagon 1 mg	● Vytorin 10-10 mg Tablet
● Januvia 100 mg Tablet	● Zemplar 4 mg
● Lamictal XR 100 mg Tablet	● Zytiga 250 mg Tablet

The second set of data collected represents the historical patient demand for the MTF/pharmaceutical combinations that were identified for analysis. The data set that was found to most closely represent the historical patient demand for the identified MTF/pharmaceutical combinations was the dispensing records from each of the

respective MTF pharmacies. While this data set does not include any unfilled patient demand that may have occurred during the time period of 1/1/2012 through 9/19/2014, it is substantially representative of the overall patient demand. The MTF pharmaceutical dispensing records were provided by the 711<sup>th</sup> Human Performance Wing through an ad hoc query within the Military Health System Management Analysis and Reporting Tool (M2).

The third set of data collected for the study represents the procurement of the identified pharmaceuticals from the PPV. This recorded activity signifies the respective MTF pharmacies receiving a resupply of stock to counterbalance previous patient disbursements of the pharmaceuticals being studied. This data set was then converted to match the units of supply found within the patient demand data. For example, one bottle of the Celebrex 100 mg pharmaceutical was converted to represent the 500 tablets contained within the PPV supplied bottle. The PPV sales of the identified pharmaceuticals was provided by the AFMOA/SGAL office through an ad hoc query within the DMLSS system.

The fourth and final data set that was required to be collected for the inventory analysis study was the suggested stock levels for the MTF/pharmaceutical combinations as found in the DMLSS CAIM module. These suggested stock levels were sought as an estimation of the 1/1/2012 beginning inventory positions in lieu of the actual beginning inventory position not being available for use in this study. The use of the suggested stock levels was chosen as a conservative approach based on the likelihood that it understates the actual beginning inventory positions found on 1/1/2012. Therefore, the suggested stock levels were used as the beginning 1/1/2012 inventory position unless it

was discovered to be insufficient in providing estimated inventory positions that did not fall below zero during the time frame of the study. Inventory positions falling below zero, signifying a stockout, were not permitted to occur in the estimated timeline of inventory positions because the data set representing patient demand included only demand that was filled. The suggested inventory stock level data set was also provided by the AFMOA/SGAL office through an ad hoc query of the DMLSS system.

### **Estimation of Historical Inventory Positions**

The first step required to perform the cost savings comparison analysis was to determine the existing inventory state upon which a comparison was to be drawn from. As previously discussed, daily inventory positions for the MTF/pharmaceutical combinations were not available for use in the study. Therefore, an estimation of the historical inventory positions were drawn in accordance with the data that was made available for the study. The calculations found in Equation 2 were used to estimate the historical daily inventory positions of the respective MTF/pharmaceutical combinations.

It should be noted that the pharmaceutical returns data used in Equation 2 begins in September 2012 and not 1/1/2012. This is based on the idea that the daily inventory position estimates begin on 1/1/2012 with fresh stock that would not be returned to the reverse logistics vendor during the early portion of the study's timeline. Occurrences in September 2012 represent a realistic time frame upon which unused stock from the start of the timeline would be nearing or past expiration and therefore warrant inventory return actions. Additionally, the number of units procured from the PPV is represented

by the previous duty day's order request for the respective pharmaceutical. This is based on the PPV's 24 hour delivery lead time that was previously discussed in Chapter 1.

$$I_i = (I_{i-1} + P) - (D + R) \quad (2)$$

Where

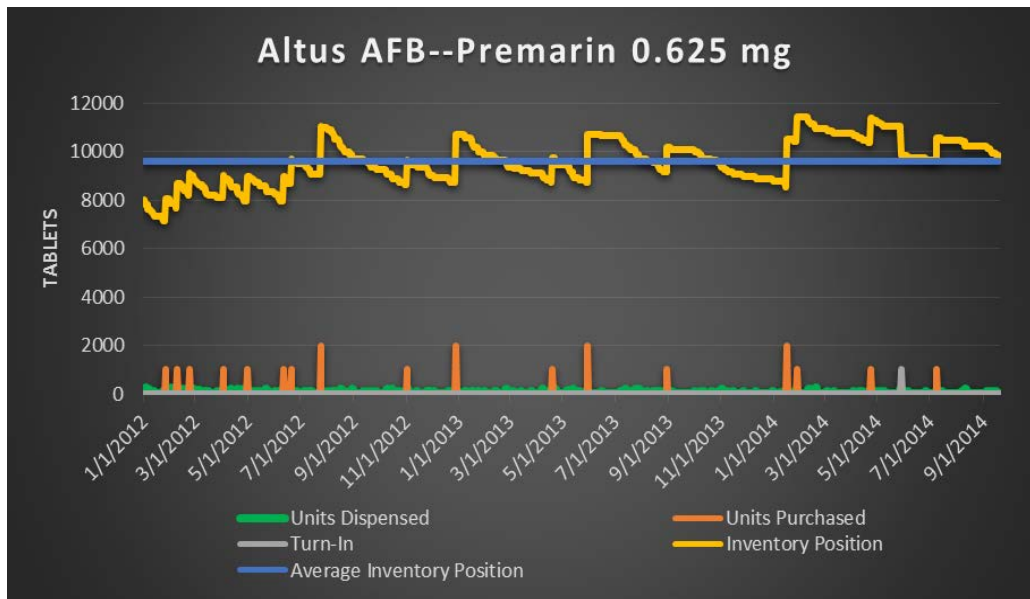
$I$  = Inventory Position

$P$  = Number of Units Procured from the PPV

$D$  = Number of Units Demanded

$R$  = Number of Units Returned

After the estimated daily inventory position for days 1/1/2012 through 9/19/2014 were calculated, an average inventory position was calculated. Figure 4 displays a graphical representation of the estimated daily inventory position timeline for Premarin 0.625 mg at Altus AFB.



**Figure 4: Daily Inventory Position Timeline for Premarin 0.625 mg at Altus AFB**

### Calculation of an Alternative Order-Up-To Stock Level

The next phase of the methodology is the calculation of an alternative stock level for the respective MTF/pharmaceutical combination. Guided by the study's research questions, the primary objectives in determining an alternative stock level is that it achieves expiration and on-hand inventory savings for the MTF, while limiting the number of potential stockout occurrences that are typically associated with lower levels of stock. Based on these objectives, Equations 3 through 5 were chosen to generate an appropriate pharmaceutical stock level.

$$S = LTD + I_{safety} \quad (3)$$

Where

S = Order-Up-To Stock Level

LTD = Average Lead Time Demand

$I_{safety}$  = Safety Stock

$$LTD = LR \quad (4)$$

Where

L = Average Replenishment Lead Time

R = Average Demand Rate (Mean)

$$I_{safety} = t\sqrt{(L \times \sigma_R^2) + (R^2 \times \sigma_L^2)} \quad (5)$$

Where

$t$  = Service Level Factor

$\sigma_R^2$  = Variance of Demand

$\sigma_L^2$  = Variance of Lead Time

Based on the assumption that the average delivery lead time is fixed at one day (24 hours) with a lead time variance of zero, the safety stock calculation seen in Equation 5 is reduced to the desired service level factor multiplied by the standard deviation of demand for the purposes of this study. The Type 2 service level factor component of the equation is represented by the t statistic that corresponds to the desired fill rate (Shivsharan, 2012:6). The t statistic was chosen over the more commonly used z statistic based on the fact that a significant number of the MTF/pharmaceutical combinations analyzed in this study possess less than 30 separate days of product demand greater than zero. Additionally, the choice of the t statistic errs on the side of caution by providing a more conservative approach. This is based on the fact that it provides a slightly higher calculation of safety stock for those pharmaceuticals possessing 30 or more separate days of product demand greater than zero.

As evidenced by the use of the t statistic, Equation 5 assumes a normal or nearly normal distribution of demand. The use of this equation with the normality assumption is common practice within industry, despite the fact that the actual distribution of demand rarely follows such a distribution. This common disregard towards the likely violation of the normality assumption is typically considered to be acceptable based on the argument that a more complicated yet accurate representation of the demand during lead time may be ineffectual because its gain in precision is comparatively small (Silver & Peterson, 1985:289). Based on this argument and its common use within industry, the use of Equation 5 with an assumed normal distribution of demand is justified despite the likely violation of the assumption.

The calculations captured in Equations 3 through 5 are applied to the respective patient demand data for the two year time period of 1/1/2012 through 12/31/2013. Days that generated zero demand are eliminated from the calculations based on the fact that the service level factor represents the pharmaceutical fill rates. Because fill rates are not computed on days with zero demand, the decision to remove these days from the order-up-to stock level calculation is valid. Table 3 displays an example of the calculations performed in determining the appropriate order-up-to stock level for the 200 mg variant of the Celebrex pharmaceutical at Goodfellow AFB. In this example, the order-up-to level is calculated to be 825.363 tablets. However, this value is rounded up to the nearest unit of sale from the PPV (bottle of 500 tablets).

**Table 3: Order-Up-To Level Calculation for Celebrex 200 mg at Goodfellow AFB**

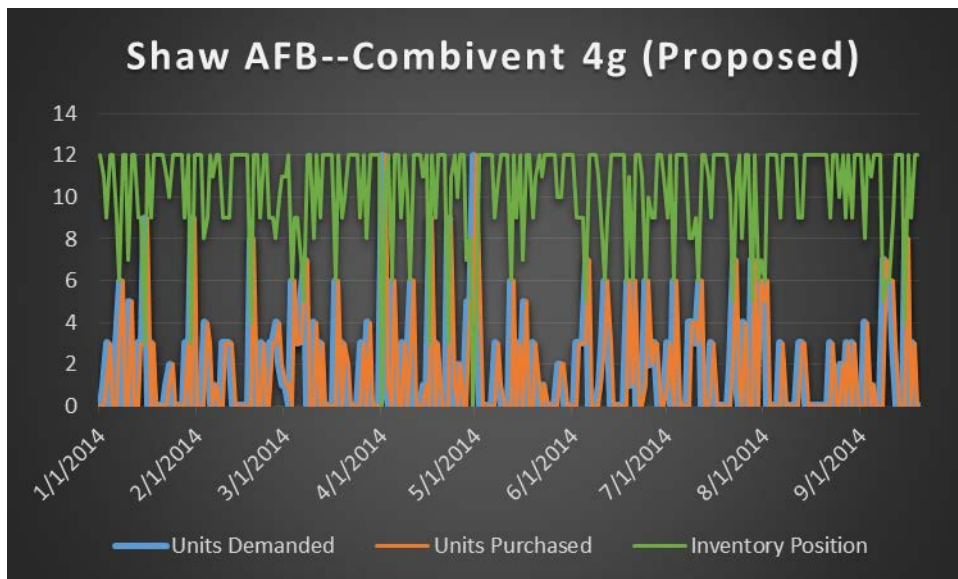
<b>Goodfellow AFB--Celebrex 200 mg</b>		
<b>Calculation</b>	<b>Value</b>	<b>Units</b>
Days w/ Demand > 0	246	days
L	1	day
R	267.862	tablets
LTD	267.862	tablets
$\sigma_R$	178.467	tablets
T-statistic (99.9%)	3.123828683	
$I_{safety}$	557.501	tablets
Order-Up-To Level (S)	825.363	tablets
<b>S (Rounded)</b>	<b>1,000</b>	<b>tablets</b>

### **Evaluation of the Alternative Stock Level**

After the alternative order-up-to stock levels for each MTF/pharmaceutical combination has been calculated, the final phase of the study's methodology is to evaluate it in terms of potential cost savings and pharmaceutical fill rates. This



evaluation is performed by testing the performance of the revised stock levels in response to the MTF/pharmaceutical's historical demand over the time period of 1/1/14 through 9/19/14. In this testing phase, the ending daily inventory position is calculated in the same manner as stated in Equation 1. Additionally, it is assumed that the MTF operates a (R, S) inventory control policy where inventory positions are reviewed at the end of each duty day. If during the review it is found that a respective pharmaceutical's inventory position has fallen below the alternative order-up-to stock level, an order is placed through the PPV that day with a delivery occurring the following morning of a duty day. The PPV order will be placed for the quantity that is necessary to bring the following duty day's beginning inventory position (after the morning PPV delivery) to a quantity that meets the alternative order-up-to stock level. Figure 5 provides a graphical illustration of the daily inventory positions for the Combivent 4g pharmaceutical at Shaw AFB, utilizing the calculated alternative order-up-to stock level of 12 units.



**Figure 5: Example of Inventory Position Using the Alternative Stock Level**

The next step in the evaluation process is to determine the Inventory Turnover (ITO) rates that the alternative order-up-to stock levels would have provided in the time period between 1/1/2014 and 9/19/2014. The calculated ITO rates are then used as an indicator for estimating the potential amount of inventory that would exceed its expiration date of clinical effectiveness under the revised inventory control policy. As previously discussed in Chapter 1, a conservative approach assumption is made for the study to apply a six month lifespan of clinical effectiveness for all pharmaceuticals procured through the PPV Generation III contract. Based on this assumption, it can be reasoned that MTF/pharmaceutical combinations exhibiting an annual ITO of two or more will not require any reverse logistics returns for reasons of expiration. Equation 6 provides the procedure for calculating the ITO rate for the time period in question.

$$\text{ITO} = \frac{\text{Average Inventory Value (\$)}}{\text{Cost of Goods Sold (\$)}} \quad (6)$$

The components of Equation 6 are quite easily found. Average Inventory Value is simply the unit cost multiplied by the average inventory position, whereas the Cost of Goods Sold is simply the summation of the number of pharmaceutical units dispensed to patients during the time period in question multiplied by the unit cost. Because the evaluation time period does not cover an entire year, the calculated ITR must be converted into an annual ITO rate. The time period of 1/1/2014 through 9/19/2014 covers 262 of the total 365 days in the year, or approximately 0.717808 years. Based on this, the ITO rates covering the time periods of 1/1/2014 through 9/19/2014 can be easily converted to an annual ITO rate by dividing it by 0.717808.

The next step in the evaluation process of the study’s methodology is to estimate the annual expiration savings for MTF/pharmaceutical combinations if the alternative order-up-to stock levels generated an annual ITO that exceeded two turns. For those MTF/pharmaceutical combinations with an annual ITO exceeding a value of two, the estimated annual savings from a pharmaceutical perishability is calculated by simply dividing the respective combination’s actual return value by two. The respective combination’s actual return value is divided by two based on the fact that the expired returns data set spanned 24 months from the 9/17/2012 through 9/16/2014.

In addition to the potential savings related to the avoidance of pharmaceutical perishability, the alternative order-up-to stock levels also provide savings potential that is realized with a reduction of on-hand stock inventories. While the estimated expiration savings has the potential to be perpetually realized on an annual basis, a reduction in on-hand stock inventories realizes a one time savings. Equation 7 displays the calculations used to estimate the potential on-hand inventory reduction savings from adopting the alternative order-up-to stock level. It should be noted that the value used for  $P$  is the average of daily inventory positions that were estimated through the calculation of Equation 2.

$$O = C \times (P - S) \tag{7}$$

Where

$O$  = On-hand Inventory Savings

$C$  = Unit Cost of the Pharmaceutical

$P$  = Average Historical Inventory Position

$S$  = Alternate Order-Up-To Stock Level

While potential savings from the avoidance of expired pharmaceutical stock and on-hand stock reductions would be very appealing to DoD financial decision makers, the realization of these potential savings would be considered impractical if it resulted in a significant increase in pharmaceutical stockouts. Therefore, the final calculation performed in this study's methodology is that of a fill rate. The fill rate is calculated by simply dividing the number of patient prescriptions that were filled by the total number of prescription demands placed by the patient for a given pharmaceutical. For example, the pharmacy at Holloman AFB would have been able to fill 1,508 out of 1,512 requests for Nexium 40 mg tablets during the time period of 1/1/14 through 9/19/2014 if they operated under the alternative order-up-to stock level of 2,070 tablets. Therefore, the pharmaceutical fill rate for Nexium at Holloman AFB was 1,508 divided by 1,512, or 99.74%. It should also be pointed out that the four stockouts that would occur for Nexium at Holloman AFB could be filled during the following duty day based on the one day delivery of the PPV.

## **Summary**

Chapter 3 provided a description of the methodology used to answer the research questions of this study. The methodology began through the collection of four distinct data sets. The patient demand, pharmaceutical vendor sales records, pharmaceutical returns and DMLSS CAIM suggested stock levels were all utilized for subsequent steps in the study's methodology. The pharmaceutical returns data was initially used to focus the scope of the study into a manageable undertaking. A combination of all four data sets were used to establish an estimated timeline of daily inventory positions from the

time period of 1/1/2012 through 9/19/2014. This estimated timeline of daily inventory positions provided a historical approximation of the respective MTF/pharmaceutical's inventory state. The patient demand data from 1/1/2012 through 12/31/2013 was later used to calculate an alternative order-up-to stock level for each of the MTF/pharmaceutical combinations. The final step of the study's methodology was performed when the alternate order-up-to stock levels were evaluated in terms of cost savings and fill rates, with respect to the patient demand data from the time period of 1/1/2014 through 9/19/2014.

## **IV. Results and Analysis**

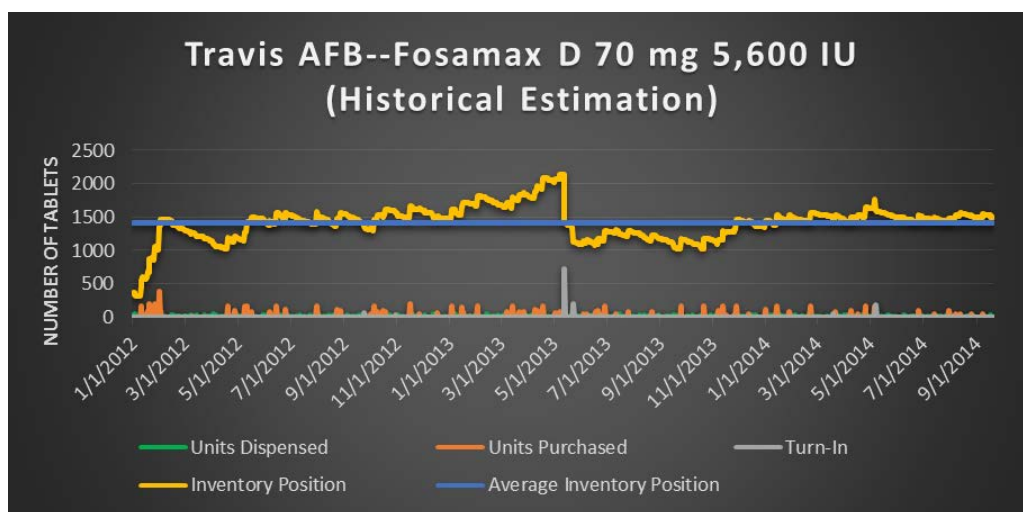
### **Chapter Overview**

This chapter summarizes the results derived from the methodology found in Chapter 3. In addition to summarizing the bottom line results of the overall study, this chapter will provide in depth analysis on a sampling of the 173 MTF/pharmaceutical combinations studied. The first MTF/pharmaceutical chosen for analysis provides opportunity for significant cost savings while also maintaining a 100 percent fill rate given the use of the calculated alternative order-up-to stock level. The second combination chosen for analysis provides an opportunity for moderate cost savings while also delivering a nearly perfect fill rate. The third MTF/pharmaceutical chosen for analysis provides a modest potential for cost savings while also delivering one of the lowest fill rates found in the study. This chapter will also provide insight into the MTF/pharmaceutical combinations that were found to exhibit turnover rates that fell below 2.

### **Travis AFB—Fosamax D 70 mg 5,600 IU**

The examination of the Fosamax D 70 mg 5,600 IU pharmaceutical at Travis AFB revealed a substantial opportunity for cost savings. Figure 6 displays the calculated estimate of the MTF/pharmaceutical's daily inventory position over the time period of 1/1/2012 through 9/19/2014. The starting inventory position of 1/1/2012 is represented by the DMLSS CAIM suggested stock level of 94 packages containing four tablets each (376 tablets). As a result of a large number of purchases from the PPV in January and February 2012, the daily inventory position of the MTF/pharmaceutical

combination quickly escalated to approximately 1,500 tablets. After maintaining this inventory position for approximately 12 months, the inventory position grew in March 2013 to reach a high of approximately 2,150 tablets. Two sizeable turn-ins of expired pharmaceuticals in May 2013 reduced the inventory position to a level that fell below 1,000 tablets. Throughout the estimated timeline, the Fosamax D 70 mg 5,600 IU pharmaceutical at Travis AFB exhibited an average inventory position of 1,420 tablets.



**Figure 6: Daily Inventory Position Timeline for Fosamax D 70 mg at Travis AFB**

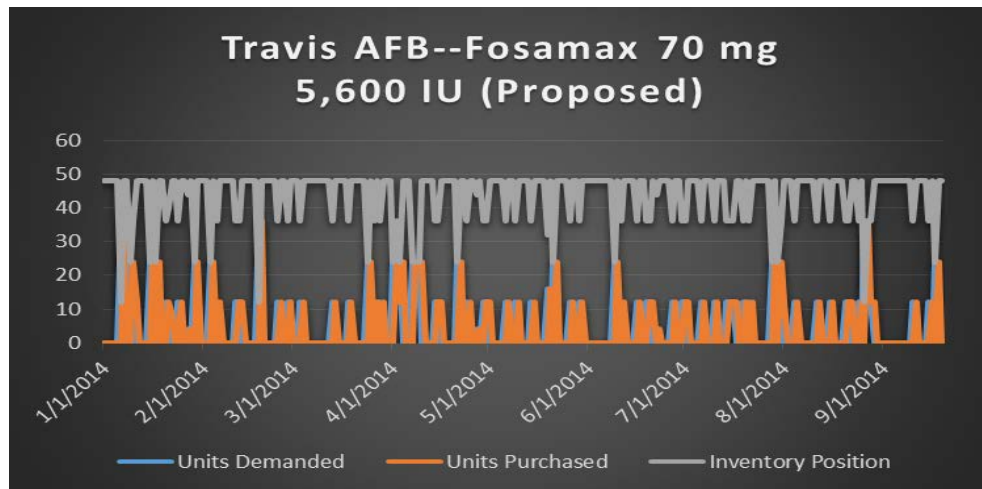
With visual evidence suggesting that an average inventory position of 1,420 tablets of Fosamax D 70 mg was excessive given the daily demand at Travis AFB, the next step was to calculate an alternative order-up-to stock level. During the time period of 1/1/2012 through 12/31/2013, there were 333 days where at least one prescription of Fosamax D 70 mg 5,600 IU was demanded. Applying Equation 3 to the patient demand of these 333 days, the LTD component was calculated at 16.8048 tablets with the  $I_{safety}$  component calculated at 27.4 tablets. The addition of these two components produces the order-up-to stock level to a value of 44.2049 tablets. Based on the Fosamax D 70 mg 5,600 IU pharmaceutical being sold in packages of 4 tablets, the order-up-to stock

level is rounded up to 48 tablets. Table 4 displays a summary of the order-up-to stock level calculations for Fosamax D 70 mg at Travis AFB.

**Table 4: Order-Up-To Level Calculation for Fosamax D 70 mg at Travis AFB**

<b>Travis AFB--Fosamax D 70 mg 5,600 IU</b>		
<b>Calculation</b>	<b>Value</b>	<b>Units</b>
Days w/ Demand > 0	333	days
L	1	day
R	16.8048	tablets
LTD	16.8048	tablets
$\sigma_R$	8.79627	tablets
T-statistic (99.9%)	3.114960539	
$I_{safety}$	27.4	tablets
Order-Up-To Level (S)	44.2049	tablets
<b>S (Rounded)</b>	<b>48</b>	<b>tablets</b>

The calculated alternative order-up-to stock level of 48 tablets was then applied to the patient demand during the time period of 1/1/2014 through 9/19/2014 and evaluated in terms of potential cost savings and fill rate. Figure 7 displays the daily inventory position for Fosamax D 70 mg 5,600 IU at Travis AFB, given the use of the (R, S) inventory control policy with an order-up-to stock level of 48 tablets.



**Figure 7: Inventory Position Timeline for Fosamax D 70 mg at Travis AFB Using the Alternative Order-Up-To Stock Level in a (R, S) Inventory Control Policy**



The alternative order-up-to stock level provided an annual ITO rate of 33.09 times. Because the ITO rate exceeded a minimum of 2 turns, an annual savings from expired Fosamax D 70 mg 5,600 IU at Travis AFB was estimated at \$8,370.18. In addition to this annual savings, an estimated one time savings of \$18,863.53 would be achieved by reducing the average inventory position of 1,420 tablets down to 48 tablets. In spite of the substantial inventory reduction, the Travis pharmacy would have been capable of filling all 98 of the prescription demands it experienced in the time period of 1/1/2014 through 9/19/2014. Table 5 provides a summary of the results found when applying the alternative order-up-to stock level of 48 Fosamax D 70 mg 5,600 IU tablets at Travis AFB.

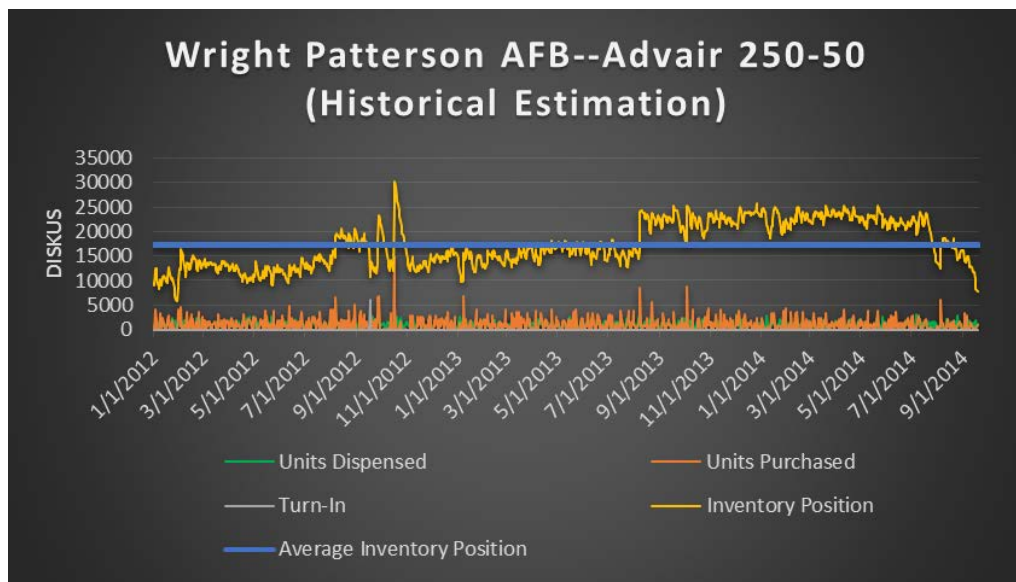
**Table 5: Evaluation Results of the Alternative Order-Up-To Stock Level for Fosamax D 70 mg 5,600 IU at Travis AFB**

<b>Travis AFB--Fosamax D 70 mg 5,600 IU</b>	
<b>Measurement</b>	<b>Results</b>
Inventory Turnover Rate	33.09
Annual Expiration Savings	\$8,370.18
On-Hand Stock Savings	\$18,863.53
Prescriptions Requested	98
Prescriptions Filled	98
Fill Rate	100%

**Wright Patterson AFB—Advair 250-50 Diskus**

The examination of the Advair 250-50 Diskus pharmaceutical at Wright Patterson AFB revealed a moderate opportunity for cost savings. Figure 8 displays the calculated estimate of the MTF/pharmaceutical’s daily inventory position over the time period of 1/1/2012 through 9/19/2014. The starting inventory position of 1/1/2012 is represented by the DMLSS CAIM suggested stock level of 9,804 individual diskus. With a few

fleeting exceptions, the inventory position of Advair 250-50 Diskus at Wright Patterson was maintained within a range of 10,000 and 20,000 diskus during the time period of January 2012 through September 2013. On 9/17/2012, the Wright Patterson AFB pharmacy recorded a substantial turn-in of 6,000 expired Advair 250-50 diskus. A major purchase through the PPV on 10/16/2012 resulted in the inventory position peaking at just above 30,000 diskus before it quickly returned back into the 12,000 to 18,000 diskus range for the next 11 months. During September 2013 through August 2014, the inventory position once again expanded into a range between 21,000 and 25,000 diskus. From August 2014 through the end of the timeline, the inventory position declined and fell to a low of 7,824 diskus. Throughout the estimated timeline of 1/1/2012 through 9/19/2014, the Advair 250-50 pharmaceutical at Wright Patterson AFB exhibited an average inventory position of 17,354 diskus.



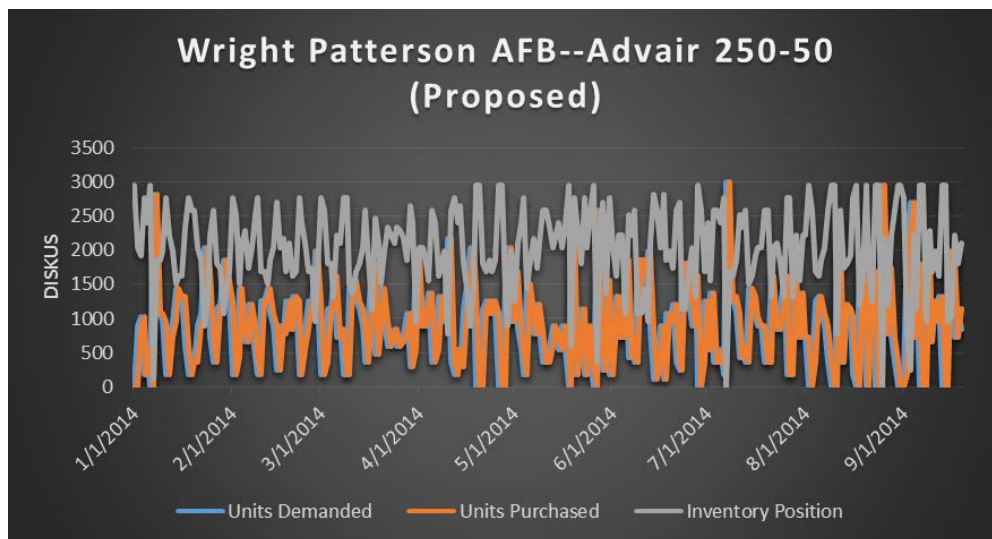
**Figure 8: Daily Inventory Position Timeline for Advair 250-50 at Wright Patterson AFB (Historical Estimation)**

With visual evidence suggesting that an average inventory position of 17,354 diskus of Advair 250-50 was excessive given the daily demand at Wright Patterson AFB, the next step was to calculate an alternative order-up-to stock level. During the time period of 1/1/2012 through 12/31/2103, there were 688 days where at least one prescription of Advair 250-50 was demanded at Wright Patterson AFB. Applying Equation 3 to the patient demand of these 688 days, the LTD component was calculated at 1,070.15 diskus with the  $I_{safety}$  component calculated at 1,840.25 diskus. The addition of these two components produces the order-up-to stock level to a value of 2,910.40 diskus. Because it is impossible to have an order-up-to stock level of 2,910.40 diskus, the value was rounded to the nearest unit of sale. Based on the Advair 250-50 pharmaceutical being sold in cartons of 60 diskus, the order-up-to stock level is rounded up to 2,940 diskus. Table 6 displays a summary of the order-up-to stock level calculations for Advair 250-50 at Wright Patterson AFB.

**Table 6: Order-Up-To Level Calculation for Advair 250-50 at Wright Patterson AFB**

<b>Wright Patterson AFB--Advair 250-50</b>		
<b>Calculation</b>	<b>Value</b>	<b>Units</b>
Days w/ Demand > 0	688	days
L	<b>1</b>	day
R	1070.15	diskus
LTD	1070.145	diskus
$\sigma_R$	593.2213	diskus
T-statistic (99.9%)	3.102138	
$I_{safety}$	1840.25	diskus
Order-Up-To Level (S)	2910.4	diskus
<b>S (Rounded)</b>	<b>2,940</b>	<b>diskus</b>

The calculated alternative order-up-to stock level of 2,940 diskus was then applied to the patient demand during the time period of 1/1/2014 through 9/19/2014 and evaluated in terms of potential cost savings and fill rate. Figure 9 displays the daily inventory position for Advair 250-50 at Wright Patterson AFB, given the use of the (R, S) inventory control policy with an order-up-to stock level of 2,940 diskus.



**Figure 9: Inventory Position Timeline for Advair 250-50 at Wright Patterson AFB Using the Alternative Order-Up-To Stock Level in a (R, S) Inventory Control Policy**

The alternative order-up-to stock level provided an annual ITO rate of 113.53 turns. Because the annual ITO rate far exceeded the threshold of 2 turns, an annual savings from expired Advair 250-50 at Wright Patterson AFB was estimated at \$4,605.94. In addition to this annual savings, an estimated one time savings of \$21,553.69 would be achieved by reducing the average inventory position of 17,354 diskus down to 2,940 diskus. In spite of the substantial inventory reduction, the Wright Patterson pharmacy would have been capable of filling 1,436 of the total 1,437 prescription demands it experienced in the time period of 1/1/2014 through 9/19/2014.

While not a perfect fill rate, this resulted in the very high fill rate of 99.93%. Table 7 provides a summary of the results found when applying the alternative order-up-to stock level of 2,940 Advair 250-50 diskus at Wright Patterson AFB.

**Table 7: Evaluation Results of the Alternative Order-Up-To Stock Level for Advair 250-50 at Wright Patterson AFB**

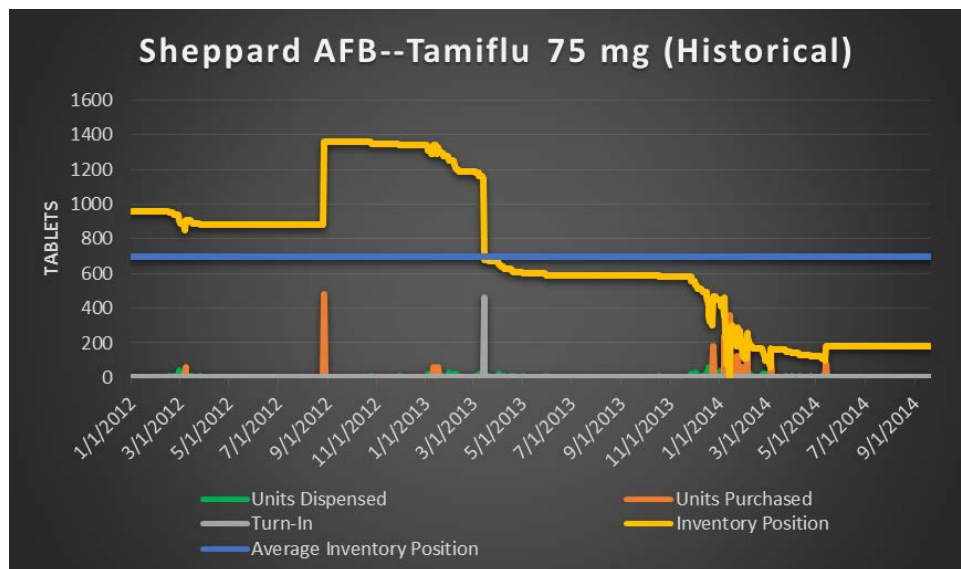
<b>Wright Patterson AFB—Advair 250-50</b>	
<b>Measurement</b>	<b>Results</b>
Inventory Turnover Rate	113.53
Annual Expiration Savings	\$4,605.94
On-Hand Stock Savings	\$21,553.69
Prescriptions Requested	1,437
Prescriptions Filled	1,436
Fill Rate	99.93%

**Sheppard AFB—Tamiflu 75 mg**

The examination of the Tamiflu 75 mg pharmaceutical at Sheppard AFB revealed a comparatively modest opportunity for cost savings. Figure 10 displays the calculated estimate of the MTF/pharmaceutical combination’s daily inventory position over the time period of 1/1/2012 through 9/19/2014. The Sheppard AFB/Tamiflu 75 mg combination is one of the examples where the DMLSS CAIM suggested stock level was not sufficient enough to prevent stockouts in the historical estimation. Based on this, a starting inventory position of 960 tablets was chosen based on it representing the lowest stock level that prevented any stockouts from occurring in the historical estimation.

With the exception two major transactions, there was very little activity that occurred with respect to the Tamiflu 75 mg pharmaceutical at Sheppard AFB over the first two years of the estimated historical timeline. The two major transactions that took

place during those first two years was a purchase from the PPV in the amount of 480 tablets on August 27, 2012 followed by a return 460 tablets of the Tamiflu 75 mg pharmaceutical on 3/14/2014. However, the third year of the timeline experienced a larger amount of activity, temporarily bringing the inventory position down to zero. Throughout the estimated timeline of 1/1/2012 through 9/19/2014, the Tamiflu 75 mg pharmaceutical at Sheppard AFB exhibited an average inventory position of 698 tablets.



**Figure 10: Daily Inventory Position Timeline for Tamiflu 75 mg at Sheppard AFB (Historical Estimation)**

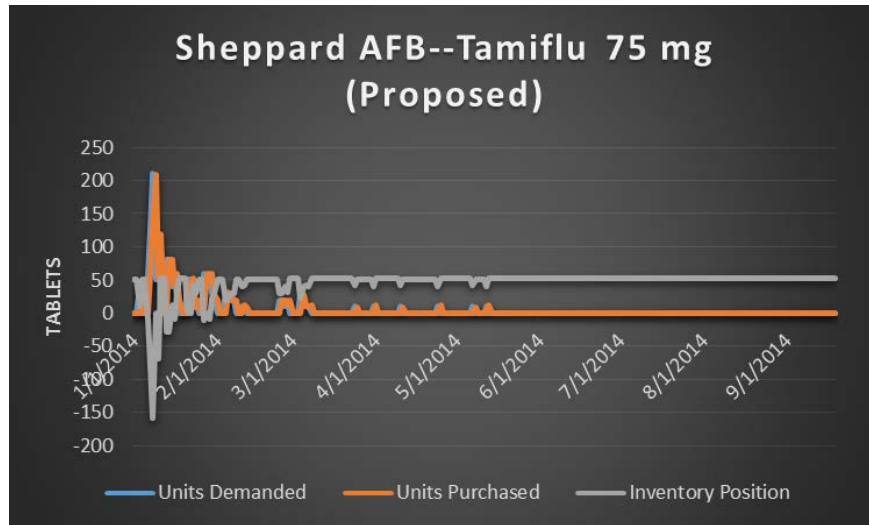
The next step in the study’s methodology was to calculate an alternate order-up-to stock level. During the time period of 1/1/2012 through 12/31/2103, there were 54 days where at least one prescription of Tamiflu 75 mg was demanded. Applying Equation 3 to the patient demand of these 54 days, the LTD component was calculated at 16.48148 tablets with the  $I_{safety}$  component calculated at 32.3018 tablets. The addition of these two components produces the order-up-to stock level to a value of 48.7833 tablets. Based on the Tamiflu 75 mg pharmaceutical being sold in packages of 10 tablets, the order-up-to

stock level was rounded up to 50 tablets. Table 8 displays a summary of the order-up-to stock level calculations for Tamiflu 75 mg at Sheppard AFB.

**Table 8: Order-Up-To Level Calculation for Tamiflu 75 mg at Sheppard AFB**

<b>Sheppard AFB--Tamiflu 75 mg</b>		
<b>Calculation</b>	<b>Value</b>	<b>Units</b>
Days w/ Demand > 0	54	days
L	1	day
R	16.48148	tablets
LTD	16.48148	tablets
$\sigma_R$	9.93515	tablets
T-statistic (99.9%)	3.251268	
$I_{safety}$	32.3018	tablets
Order-Up-To Level (S)	48.7833	tablets
<b>S (Rounded)</b>	<b>50</b>	<b>tablets</b>

The calculated alternative order-up-to stock level of 50 tablets was then applied to the patient demand during the time period of 1/1/2014 through 9/19/2014 and evaluated in terms of potential cost savings and fill rate. Figure 11 displays the daily inventory position for Tamiflu 70 mg at Sheppard AFB, given the use of the (R, S) inventory control policy with an order-up-to stock level of 50 tablets. Looking at Figure 11, it is quite apparent that the calculated alternative order-up-to stock level of 50 was not substantial enough to prevent a significant number of stockouts that would have occurred at the beginning of the 2014 calendar year. This is primarily due to the lower patient demand for Tamiflu 75 mg in 2012 and 2013 not providing a suitable prediction basis for the larger amount of patient demand that occurred in 2014.



**Figure 11: Inventory Position Timeline for Tamiflu 70 mg at Sheppard AFB Using the Alternative Order-Up-To Stock Level in a (R, S) Inventory Control Policy**

Despite the apparent failures of the calculated alternative order-up-to stock level for this MTF/pharmaceutical combination, the evaluation process within the methodology was pursued. The alternative order-up-to stock level provided an annual ITO rate of 43.19 times. Because the ITO rate far exceeded the threshold of 2 turns, an annual savings from expired Tamiflu 75 mg at Sheppard AFB was estimated at \$331.81. In addition to this annual savings, an estimated one time savings of \$1,401.89 would be achieved by reducing the average inventory position of 698 tablets down to 50 tablets. As was expected, the Sheppard pharmacy would have been capable of filling only 114 of the total 155 prescription demands it experienced in the time period of 1/1/2014 through 9/19/2014 given an order-up-to stock level of 50 tablets. This results in a very poor fill rate of 73.55%. Table 9 provides a summary of the results found when applying the alternative order-up-to stock level of 50 Tamiflu 70 mg tablets at Sheppard AFB.



**Table 9: Evaluation Results of the Alternative Order-Up-To Stock Level for Tamiflu 75 mg at Sheppard AFB**

<b>Sheppard AFB—Tamiflu 75 mg</b>	
<b>Measurement</b>	<b>Results</b>
Inventory Turnover Rate	43.19
Annual Expiration Savings	\$331.81
On-Hand Stock Savings	\$1,401.89
Prescriptions Requested	155
Prescriptions Filled	114
Fill Rate	73.55%

**MTF/Pharmaceutical Combinations with Low Annual ITO Rates**

Out of the total 173 MTF/pharmaceutical combinations analyzed in the study, 18 of the combinations exhibited Annual ITO rates below 2 turns during the time period of 1/1/2014 through 9/19/2014 given their alternative order-up-to stock levels. Table 10 displays these 18 combinations with the corresponding annual ITO rates.

**Table 10: MTF/Pharmaceutical Combinations with Annual ITO Rates Below 2**

<b>Pharmaceutical</b>	<b>Base</b>	<b>Avg. On-Hand Savings</b>	<b>Fill Requests</b>	<b>Stockouts</b>	<b>Fill Rate</b>	<b>Annual ITO</b>
Acetasol HC	Andrews	\$3,585.89	1	0	100%	1.39
Avonex 30 mg	Lackland	\$27,362.48	2	0	100%	0.76
Fosamax D 70-2,800	Mt. Home	\$2,063.39	2	0	100%	1.04
Fosamax D 70-5,600	Kirtland	\$4,272.68	1	0	100%	0.84
Fosamax D 70-5,600	Maxwell	\$915.42	1	0	100%	0.22
Gleevec 400 mg	Keesler	\$14,930.42	2	0	100%	1.67
Gleevec 400 mg	Moody	\$2,585.76	2	0	100%	1.39
Lamictal 100 mg	Andrews	\$792.81	4	0	100%	1.28
Lamictal 100 mg	Kirtland	\$280.00	1	0	100%	0.08
Lamictal 100 mg	Seymour J.	\$24,582.32	0	0	N/A	0
Mefloquine 250 mg	Hill	\$1,805.43	3	0	100%	0.78
Mefloquine 250 mg	Lackland	\$14,386.76	3	0	100%	0.09
Mefloquine 250 mg	Little Rock	\$355.25	4	0	100%	0.82
Mefloquine 250 mg	Offutt	\$1,455.25	3	0	100%	1.34
Mefloquine 250 mg	Robins	\$1,434.06	3	0	100%	0.47
Pancreaze DR	Andrews	\$1,784.16	1	0	100%	1.25
Sandostatin 30 mg	Lackland	\$12,452.74	2	0	100%	0.93
Zemplar 4 mg	Lackland	\$10,159.68	1	0	100%	1.39

Over the two year time period of September 2012 through September 2014, these 18 MTF/pharmaceutical combinations accounted for \$46,441.08 (average annual cost of \$23,220.54) in pharmaceutical returns. Based on their annual ITO rates being below the threshold of 2 turns per year, there is no way of completely eliminating perishability costs for these combinations given the calculated order-up-to stock levels. With that stated, the alternative order-up-to stock levels for these 18 combinations would most certainly reduce the perishability cost to levels lower than was previously experienced. In addition a reduction in perishability costs, the use of the calculated order-up-to stock level would provide a one time on-hand inventory reduction savings of \$125,204.50.

### **Summary**

Upon analysis of the 173 MTF/pharmaceutical combinations within the scope of this study, it was determined the use of an alternative order-up-to stock level in a (R, S) inventory control policy could save the AFMS a significant amount of money in cost reductions. Table 11 displays a summary of the results generated by the 155 MTF/pharmaceutical combinations that exhibited an annual ITO that exceeded the 2 turn threshold. Using the alternative order-up-to stock levels would have provided an estimated annual perishability cost reduction of \$419,504.10.

In addition to the annual perishability cost savings, the study found that the adoption of the alternative order-up-to stock levels could provide the AFMS with a one-time inventory reduction savings of approximately \$1,769,138.82. This figure includes the 155 MTF/pharmaceutical combinations with annual ITOs above 2 turns, as well as the 18 combinations with annual ITOs below 2 turns. In spite of the inventory

reductions that would occur with the use of the alternative order-up-to stock levels in a (R, S) inventory control policy, the evaluation phase of the methodology determined that the overall fill rate amongst the studied MTF/pharmaceutical combinations would be above 99.8%. A breakdown of the individual MTF/pharmaceutical combination results can be found in Appendix A through AF.

**Table 11: Summary of Results by Pharmaceutical**

Pharmaceutical	Savings		1/1/2014 - 9/19/2014		
	Annual Expiration	Average On-Hand	Fill Rate Requests	Stockouts	Fill Rate
Abilify 30 mg	\$30,618.84	\$69,790.13	72	1	98.61%
Acetasol HC	\$13,465.13	\$23,115.46	95	0	100.00%
Advair 250-50	\$11,423.82	\$74,371.09	4,125	0	100.00%
Agrylin 0.5 mg	\$15,929.75	\$18,472.50	8	0	100.00%
Avonex 30 mg	\$10,118.42	\$47,398.02	32	0	100.00%
Celebrex 100 mg	\$5,917.95	\$94,270.77	1,784	0	100.00%
Celebrex 200 mg	\$14,917.89	\$66,560.13	320	0	100.00%
Combivent 4 g	\$12,055.01	\$30,953.02	512	3	99.41%
Epipen	\$19,091.93	\$133,359.48	2,581	13	99.50%
Fosamax D 70-2,800	\$15,795.77	\$24,606.95	541	3	99.45%
Fosamax D 70-5,600	\$27,674.01	\$57,703.05	285	2	99.30%
Gleevec 100 mg	\$6,838.95	\$21,481.59	18	0	100.00%
Gleevec 400 mg	\$19,280.18	\$14,914.51	41	0	100.00%
Glucagon 1 mg	\$14,497.62	\$79,772.01	928	6	99.35%
Januvia 100 mg	\$3,760.20	\$67,138.54	2,871	4	99.86%
Levitra 10 mg	\$10,976.00	\$70,597.37	33	0	100.00%
Nexium 40 mg	\$23,078.00	\$141,716.94	37,901	4	99.99%
Pancreaze 16,800 IU	\$6,360.41	\$38,323.89	113	1	99.12%
Premarin 0.3mg	\$16,773.20	\$87,245.01	1,143	0	100.00%
Premarin 0.625 mg	\$16,276.67	\$76,003.38	1,265	0	100.00%
Premarin 1.25 mg	\$29,810.28	\$87,867.18	498	0	100.00%
Prograf 5mg	\$21,243.69	\$58,137.21	14	0	100.00%
Sandostatin 30 mg	\$3,913.85	\$11,269.88	9	0	100.00%
Spiriva 18 mcg	\$9,673.62	\$73,976.60	5,601	11	99.80%
Tamiflu 75 mg	\$13,032.38	\$32,206.87	785	63	91.97%
Tobradex 5 ml	\$8,678.88	\$17,024.00	45	0	100.00%
Votrient 30 mg	\$17,207.21	\$10,357.55	4	0	100.00%
Vytorin 10 mg	\$8,286.93	\$60,222.12	541	0	100.00%
Zytiga 250 mg	\$12,807.59	\$55,079.07	28	3	89.29%
<b>Totals</b>	<b>\$419,504.10</b>	<b>\$1,643,934.32</b>	<b>62,193</b>	<b>114</b>	<b>99.82%</b>

In the case of a MTF returning a pharmaceutical to the reverse logistics vendor prior to its expiration date, the MTF receives a credit to be used in future procurement of other pharmaceuticals through the PPV. The amount of the credit is not a static figure and depends on factors such as the remaining lifespan of the pharmaceutical and the manufacturer’s unique return policy. Despite the varying credit amounts received by MTF, a representative from the AFMOA/SGAL office provided an estimate of approximately 40% of the returned pharmaceutical’s retail value. In response to the shifting credit returns rate experienced by MTFs, Table 12 displays the effective perishability cost savings of the studied MTF/pharmaceutical combinations given a credit returns range of 30 through 50 percent.

**Table 12: Sensitivity Table for Effective Perishability Cost Savings**

<b>Credit %</b>	<b>Effective Perishability Cost Savings</b>
30	\$293,652.87
35	\$272,677.67
<b>40</b>	<b>\$251,702.46</b>
45	\$230,727.26
50	\$209,752.05

Table 12 extends the benefit of doubt and treats all returns of the studied combinations as possessing a remaining lifespan of clinical effectiveness upon the date of return and therefore triggering a credit to be issued. Although unlikely that each and every one of the studied returns had not reached the end of its expiration date, the AFMS would achieve an effective perishability cost savings of approximately \$209,752.05 on the low-end and \$293,652.87 on the high-end each year by using the alternative order-up-to stock level for the studied MTF/pharmaceutical combinations. Assuming that the AFMOA/SGAL office estimate of a credit equaling 40 percent of the pharmaceutical’s

retail value, the AFMS would achieve a perishability cost savings of approximately \$251,702.46 each year using the methodology found in Chapter 3.

## **V. Conclusions and Recommendations**

### **Overview**

The chapter begins by summarizing the study by answering the research questions that were posed in Chapter 1 and concludes with recommendations for action and future research.

### **Summary of the Research and Answers to the Research Questions**

This study analyzed a total of 173 MTF/pharmaceutical combinations with respect to their historical inventory practices over the time period of 1/1/2012 through 9/19/2014. At the conclusion of the analysis, it was determined that the respective MTF pharmacies were holding an excessive amount of pharmaceutical stock, given the contractual performance service agreements they held with their respective PPV. The unique aspect of this study is that it was the first known to apply patient demand to the pharmaceutical inventory analysis, whereas previous efforts utilized prior PPV sales as a substitute for the demand function.

The research effort applied a basic inventory management calculation to the patient pharmaceutical demand data as a means to determine an alternative order-up-to stock level for each of the respective MTF/pharmaceutical combinations. The alternative order-up-to stock levels were then evaluated against the 1/1/2014 through 9/19/2014 patient demand data in terms of cost savings and fill rates. The ensuing estimated cost savings and fill rate results were then used to answer the three research questions posed in the study.

1. What cost savings can the AFMS realize in terms of reducing the amount of expired or near expired pharmaceutical returns, given the application of an inventory control system that utilizes adjusted order-up-to stock level quantities?

Out of the 155 MTF/pharmaceutical combinations studied that exhibited an annual ITO rate exceeding the 2 turn threshold, it is estimated that the AFMS could save \$419,504.10 annually. Because the AFMS receives credits for the return of pharmaceuticals with a remaining lifespan, the effective savings rate realized by the AFMS would be less than the \$419,504.10. Using a conservative approach and assuming the unlikely event that all of the returns possessed a lifespan of clinical usefulness upon the return date, the effective savings for the 155 MTF/pharmaceutical combinations ranged from \$209,752.05 to \$293,652.87.

2. What cost savings can the AFMS realize in terms of reducing on-hand pharmaceutical stock, given the application of an inventory control system that utilizes adjusted order-up-to stock level quantities?

Out of the 173 MTF/pharmaceutical combinations analyzed in this study, it was estimated that the use of the (R, S) inventory control policy with the calculated alternative order-up-to stock levels would provide the AFMS with a one time inventory reduction savings of \$1,769,138.82.

3. What impact will the proposed inventory control system have on pharmaceutical fill rates?

Aggregated across the 173 MTF/pharmaceutical combinations analyzed in this study, it was determined that the overall fill rate would have exceeded 99.82 percent. In other terms, the collection of MTFs studied would have been unable to fill 114 of the 62,193 prescriptions that were demanded during the time period of 1/1/2014 through 9/19/2014. While the aggregated fill rate across all of the studied combinations is

reasonably high given the cost savings trade-off, there were two pharmaceuticals that exhibited undesirable fill rates, namely Tamiflu 75 mg and Zytiga 250 mg.

The primary cause of the undesirable fill rates amongst these two pharmaceuticals is that the patient demand pattern changed considerably from the data used to calculate the alternative order-up-to stock level (1/1/2012 through 12/31/2013) to the data used to evaluate the alternative order-up-to stock level (1/1/2014 through 9/19/2014). Because it is extremely difficult for statistical analysis to forecast extreme shifts in demand, the AFMS would continue rely on the expertise and experience of the clinical staff to provide inventory policy recommendations on pharmaceuticals whose demand is projected to change. For example, the clinical staff may have been alerted to a heightened flu season in 2014 and therefore made a recommendation for the pharmacy to modify the calculated order-up-to stock levels accordingly for the Tamiflu 75 mg pharmaceutical.

### **Recommendations for Action**

Based on the assumption that AFMS leadership regards a 99.82% fill rate as a palatable trade-off for the cost savings ascertained in this study, it is recommended that a pilot study be conducted with one or more of the MTF/pharmaceutical combinations identified in this research effort. Conducting a pilot study on a small scale will allow AFMS leadership to evaluate the feasibility of implementing the proposed inventory control policy with a calculated alternative order-up-to stock level using patient demand. In addition to providing a mechanism for evaluating the inventory control policy's



feasibility, a pilot study would allow AFMS leadership to evaluate changes in actual cost savings, fill rates, and patient satisfaction rates.

A secondary recommendation stemming from this research effort suggests that all pharmaceuticals exhibiting an annual ITO rate below 2 turns should be evaluated by the MTF's clinical staff in terms of approving or disapproving its continuation on the clinic's formulary. While there are certainly cases where a pharmaceutical with an annual ITO rate below 2 turns should be retained on a pharmacy's formulary (i.e., lifesaving pharmaceuticals in an inpatient hospital), there are other cases where the preservation of a slow-moving pharmaceutical on the MTF formulary is not cost effective or clinically warranted. Given access to the costs associated with pharmaceuticals exhibiting low annual ITO rates, the MTF's clinical staff will be provided the information necessary to make an appropriate tradeoff decision.

### **Recommendation for Future Research**

Future research related to this study includes:

- A research effort that calculates the cost savings and fill rates in accordance with the strict utilization of the DMLSS CAIM suggested stock levels as the alternative order-up-to stock level in a (R, S) inventory control policy. Comparing these cost savings and fill rate results to the results of this study would provide insight into determining if patient demand or previous PPV sales is the better method in calculating the order-up-to stock level quantities.
- A pharmaceutical inventory and safety stock analysis that addresses segments of Air Force medicine that was not covered in this study. Such segments include the inventory control policies of OCONUS MTFs, influenza vaccinations, and the pharmaceuticals which are stocked inherently for WRM or Medical Counter-Chemical, Biological, Radiological, and Nuclear purposes (MC-CBRN) purposes.
  - An inventory and safety stock analysis of OCONUS MTFs will require additional factors to be considered, such as the potential for longer lead time demands and higher variability in vendor fulfillment rates.

- An inventory and safety stock analysis on seasonal influenza vaccinations will need to factor in the nuances of the AFMS' flu vaccination procurement process and dissemination. Such nuances include but are not limited to the small number of orders for comparatively large quantities and the base's policy regarding the dissemination of the flu vaccinations to civilian employees of the base who are not covered by TRICARE.
- An inventory and safety stock analysis on pharmaceuticals that are stocked inherently for WRM or MC-CBRN purposes, such as the Antidote Treatment Nerve Agent Auto-Injector (ATNAA), could be conducted in search of an inventory control policy that achieves cost savings over the status quo policies while also ensuring the highest level of availability as possible.
- A study that examines the feasibility of implementing an inventory control system that, like the one proposed in this study, calculates the order-up-to stock levels in accordance with patient demand. The feasibility study could also examine the impact that implementing the proposed inventory control policy would have on pharmacy operations. One impact for analysis is the increase in order frequency that will occur as a result of implemented the proposed inventory control policy. From 1/1/2014 through 9/19/2014, the proposed inventory control policy applied to the 173 MTF/pharmaceutical combinations would have increased the number of replenishment orders from 4,576 to 12,675. As an alternative to the implementation of the proposed inventory control policy being performed by Air Force personnel, a feasibility study concerning a movement towards a Vendor Managed Inventory (VMI) system for Air Force pharmaceuticals could be explored.

**Appendix A — Abilify 30 mg Results**

<b>Abilify 30 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Eglin</b>	\$465.98	\$819.34	8	0	3.34
<b>Lackland</b>	\$28,709.03	\$44,906.12	14	0	4.76
<b>Luke</b>	\$260.90	\$9,164.06	13	1	6.69
<b>Patrick</b>	\$258.62	\$4,120.99	9	0	5.22
<b>Peterson</b>	\$225.36	\$3,536.99	6	0	4.64
<b>Randolph</b>	\$698.97	\$7,242.63	22	0	6.24
<b>Total</b>	<b>\$30,618.84</b>	<b>\$69,790.13</b>	<b>72</b>	<b>1</b>	
			<b>Fill Rate</b>	<b>98.61%</b>	

## Appendix B — Acetasol HC Results

Acetasol HC					
	Savings		1/1/2014 - 9/19/2014		
Base	Annual Expiration	Average On-Hand	Requests	Stockouts	Turnover
Andrews	\$0	\$3,586	1	0	1.39
Charleston	\$1,426	\$1,229	9	0	4.18
Lackland	\$204	\$390	7	0	4.88
Langley	\$2,241	\$5,998	9	0	4.18
Luke	\$2,706	\$2,189	19	0	11.61
Travis	\$4,546	\$9,552	32	0	13.1
Wright Patterson	\$2,343	\$3,758	19	0	13.23
<b>Total</b>	<b>\$13,465</b>	<b>\$26,701</b>	<b>96</b>	<b>0</b>	
			Fill Rate	100.00%	

### Appendix C — Advair 250-50 Results

Advair 250-50					
	Savings		1/1/2014 - 9/19/2014		
Base	Annual Expiration	Average On-Hand	Requests	Stockouts	Turnover
Holloman	\$1,086	\$12,709	338	0	54.74
McConnell	\$543	\$596	291	0	60.25
McGuire	\$1,794	\$9,117	431	5	74.39
Robins	\$1,077	\$5,669	451	1	69.66
Sheppard	\$1,062	\$2,186	400	0	69.51
Tinker	\$897	\$18,309	674	0	74.23
Vance	\$359	\$4,233	103	1	40.09
Wright Patterson	\$4,606	\$21,554	1437	1	113.53
Total	\$11,424	\$74,371	4125	8	
			Fill Rate	99.81%	

**Appendix D — Agrylin 0.5 mg Results**

<b>Agrylin 0.5 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Lackland</b>	\$15,929.75	\$18,472.50	8	0	3.76
<b>Total</b>	<b>\$15,929.75</b>	<b>\$18,472.50</b>	<b>8</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

## Appendix E — Avonex 30 mg Results

<b>Avonex 30 mcgs</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Andrews</b>	\$3,353.16	\$29,895.91	28	0	13.93
<b>Lackland</b>	\$0.00	\$27,362.48	2	0	0.76
<b>Travis</b>	\$6,765.26	\$17,502.11	4	0	2.79
<b>Total</b>	<b>\$10,118.42</b>	<b>\$74,760.50</b>	<b>34</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix F — Celebrex 100 mg Results**

<b>Celebrex 100 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Holloman</b>	\$1,493.15	\$5,291.23	85	0	25.08
<b>Maxwell</b>	\$1,477.73	\$4,136.82	212	0	51.47
<b>Sheppard</b>	\$728.66	\$25,230.00	188	0	31.36
<b>Tinker</b>	\$1,108.29	\$17,315.63	356	0	47.3
<b>Wright Patterson</b>	\$1,110.14	\$42,297.09	943	0	91.23
<b>Total</b>	<b>\$5,917.95</b>	<b>\$94,270.77</b>	<b>1784</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	



**Appendix G — Celebrex 200 mg Results**

<b>Celebrex 200 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Goodfellow</b>	\$14,917.89	\$66,560.13	320	0	35.9
<b>Total</b>	<b>\$14,917.89</b>	<b>\$66,560.13</b>	<b>320</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

## Appendix H — Combivent 4 gm Results

Combivent 4 gm					
	Savings		1/1/2014 - 9/19/2014		
Base	Annual Expiration	Average On-Hand	Requests	Stockouts	Turnover
Andrews	\$45.60	\$1,627.18	72	0	24.03
FE Warren	\$80.84	\$2,239.96	93	1	38.49
Goodfellow	\$2,773.41	\$1,647.02	64	1	30.45
Seymour Johnson	\$8,607.96	\$22,155.11	108	1	39.78
Shaw	\$547.20	\$3,283.75	175	0	50.62
<b>Total</b>	<b>\$12,055.01</b>	<b>\$30,953.02</b>	<b>512</b>	<b>3</b>	
			<b>Fill Rate</b>	<b>99.41%</b>	

## Appendix I — Epipen Results

Epipen					
Base	Savings		1/1/2014 - 9/19/2014		
	Annual Expiration	Average On-Hand	Requests	Stockouts	Turnover
<b>Eglin</b>	\$2,800.71	\$21,453.32	546	1	89.58
<b>FE Warren</b>	\$1,503.06	\$9,647.60	101	0	34.83
<b>Los Angeles</b>	\$1,300.94	\$615.93	73	0	24.15
<b>Langley</b>	\$3,149.87	\$17,623.18	651	4	87.87
<b>Luke</b>	\$1,922.30	\$8,582.42	350	1	70.43
<b>Maxwell</b>	\$2,022.44	\$55,888.92	251	5	72.66
<b>Mt. Home</b>	\$2,543.64	\$1,079.91	84	0	32.74
<b>Robins</b>	\$2,353.07	\$13,744.01	328	2	83.36
<b>Tyndall</b>	\$1,495.92	\$4,724.19	197	0	50.35
<b>Total</b>	<b>\$19,091.93</b>	<b>\$133,359.48</b>	<b>2581</b>	<b>13</b>	
			<b>Fill Rate</b>	<b>99.50%</b>	

**Appendix J — Fosamax 70 mg / 2,800 IU Vitamin D Results**

<b>Fosamax 70 mg / 2,800 IU Vitamin D</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Andrews</b>	\$1,433.18	\$2,024.63	27	0	12.69
<b>Barksdale</b>	\$3,566.49	\$2,297.50	22	0	10.22
<b>Keesler</b>	\$749.07	\$903.71	21	0	14.63
<b>Los Angeles</b>	\$1,689.78	\$1,531.45	34	0	17.07
<b>Luke</b>	\$853.10	\$2,063.39	2	0	13.06
<b>Mt. Home</b>	\$0.00	\$2,063.39	2	0	1.04
<b>Patrick</b>	\$5,088.11	\$12,153.79	352	0	52.24
<b>Travis</b>	\$1,186.77	\$984.15	20	0	11.94
<b>Tyndall</b>	\$1,229.28	\$2,648.33	63	3	29.43
<b>Total</b>	<b>\$15,795.77</b>	<b>\$26,670.34</b>	<b>543</b>	<b>3</b>	
			<b>Fill Rate</b>	<b>99.45%</b>	

**Appendix K — Fosamax 70 mg / 5,600 IU Vitamin D Results**

<b>Fosamax 70 mg -- 5,600 IU Vitamin D</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Barksdale</b>	\$5,734.20	\$3,838.08	4	0	3.34
<b>Eglin</b>	\$1,754.01	\$5,982.14	23	0	13.73
<b>Keesler</b>	\$2,649.00	\$7,949.72	6	0	3.13
<b>Kirtland</b>	\$0.00	\$4,272.68	1	0	0.84
<b>Langley</b>	\$1,621.22	\$7,586.95	61	0	22.67
<b>Little Rock</b>	\$1,733.62	\$2,239.55	11	0	9.19
<b>Luke</b>	\$1,392.21	\$3,393.59	8	2	6.08
<b>Maxwell</b>	\$0.00	\$915.42	1	0	0.22
<b>Offutt</b>	\$3,195.48	\$6,301.44	58	0	25.7
<b>Travis</b>	\$8,370.18	\$18,863.53	98	0	33.09
<b>Wright Patterson</b>	\$1,224.12	\$1,548.05	16	0	7.43
<b>Total</b>	<b>\$27,674.02</b>	<b>\$62,891.15</b>	<b>287</b>	<b>2</b>	
			<b>Fill Rate</b>	<b>99.30%</b>	

**Appendix L — Gleevec 100 mg Results**

<b>Gleevec 100 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Travis</b>	\$6,838.95	\$21,481.59	18	0	11.26
<b>Total</b>	<b>\$6,838.95</b>	<b>\$21,481.59</b>	<b>18</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix M — Gleevec 400 mg Results**

<b>Gleevec 400 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Keesler</b>	\$0.00	\$14,930.42	2	0	1.67
<b>Moody</b>	\$0.00	\$2,585.76	2	0	1.39
<b>Travis</b>	\$19,280.18	\$14,914.51	41	0	22.12
<b>Total</b>	<b>\$19,280.18</b>	<b>\$32,430.69</b>	<b>41</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

## Appendix N — Glucagon 1 mg Results

<b>Glucagon 1 mg</b>					
	Savings		1/1/2014 - 9/19/2014		
Base	Annual Expiration	Average On-Hand	Requests	Stockouts	Turnover
<b>Buckley</b>	\$3,520.38	\$4,631.64	37	0	15.05
<b>Dover</b>	\$280.68	\$1,479.48	13	0	4.64
<b>FE Warren</b>	\$409.68	\$1,046.72	30	0	13.23
<b>Keesler</b>	\$1,082.33	\$5,697.52	66	0	26.67
<b>Lackland</b>	\$2,339.90	\$6,065.18	238	2	46.1
<b>Langley</b>	\$1,086.92	\$1,064.43	53	0	16.02
<b>Moody</b>	\$582.45	\$2,151.73	11	0	4.53
<b>Nellis</b>	\$1,433.87	\$10,968.92	115	0	36.82
<b>Travis</b>	\$1,962.83	\$28,418.93	161	2	55.03
<b>Wright Patterson</b>	\$1,798.61	\$18,247.46	204	2	57.27
	<b>Total</b>		<b>928</b>	<b>6</b>	
	<b>\$14,497.62</b>		<b>\$79,772.01</b>	<b>Fill Rate</b>	<b>99.35%</b>



### Appendix O — Januvia 100 mg Results

<b>Januvia 100 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Goodfellow</b>	\$1,068.60	\$13,702.87	180	2	48.99
<b>Los Angeles</b>	\$89.18	\$5,069.19	264	0	72.54
<b>Malmstrom</b>	\$718.28	\$2,193.12	177	0	48.64
<b>Mt Home</b>	\$538.71	\$2,252.43	190	0	40.19
<b>Shaw</b>	\$896.45	\$7,415.23	530	2	78.61
<b>Travis</b>	\$90.44	\$25,947.83	1351	0	103.47
<b>Vance</b>	\$358.56	\$10,557.87	179	0	61.88
<b>Total</b>	<b>\$3,760.20</b>	<b>\$67,138.54</b>	<b>2871</b>	<b>4</b>	
			<b>Fill Rate</b>	<b>99.86%</b>	

**Appendix P — Lamictal 100 mg Results**

<b>Lamictal 100 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Andrews</b>	\$0.00	\$792.81	4	0	1.28
<b>Kirtland</b>	\$0.00	\$280.00	1	0	0.08
<b>Seymour J.</b>	\$0.00	\$24,582.32	0	0	0
<b>Total</b>	\$0.00	\$25,655.13	5	0	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix Q — Levitra 10 mg Results**

<b>Levitra 10 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Travis</b>	\$10,976.00	\$70,597.37	33	0	22.89
<b>Total</b>	<b>\$10,976.00</b>	<b>\$70,597.37</b>	<b>33</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix R — Mefloquine 250 mg Results**

<b>Mefloquine 250 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Hill</b>	\$0.00	\$1,805.43	3	0	0.78
<b>Lackland</b>	\$0.00	\$14,386.76	3	0	0.09
<b>Little Rock</b>	\$0.00	\$355.25	4	0	0.82
<b>Offutt</b>	\$0.00	\$1,455.25	3	0	1.34
<b>Robins</b>	\$0.00	\$1,434.06	3	0	0.47
<b>Total</b>	<b>\$0.00</b>	<b>\$19,436.75</b>	<b>16</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix S — Nexium 40 mg Results**

<b>Nexium 40 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Goodfellow</b>	\$6,971.69	\$12,963.57	1235	0	77.66
<b>Hill</b>	\$1,477.56	\$22,970.60	4557	0	121.09
<b>Holloman</b>	\$1,309.68	\$5,573.69	1512	4	93.7
<b>Little Rock</b>	\$901.76	\$1,623.82	4383	0	129.35
<b>MacDill</b>	\$4,808.64	\$50,876.17	7985	0	111.64
<b>Maxwell</b>	\$1,298.52	\$5,051.18	5765	0	129.32
<b>Robins</b>	\$3,318.87	\$12,266.13	5096	0	114.66
<b>Tinker</b>	\$1,172.28	\$27,828.08	5412	0	106.96
<b>Whiteman</b>	\$1,819.01	\$2,563.70	1956	0	101.87
<b>Total</b>	<b>\$23,078.00</b>	<b>\$141,716.94</b>	<b>37,901</b>	<b>4</b>	
			<b>Fill Rate</b>	<b>99.99%</b>	

**Appendix T — Pancreaze 16,800 IU Results**

<b>Pancreaze 16,800 UU</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Andrews</b>	\$0.00	\$1,784.16	1	0	1.25
<b>Eglin</b>	\$1,356.75	\$2,970.16	58	0	8.81
<b>Keesler</b>	\$1,389.83	\$3,936.63	6	0	2.51
<b>Lackland</b>	\$1,714.55	\$16,374.11	21	1	12.96
<b>Maxwell</b>	\$268.32	\$2,143.96	21	0	11.02
<b>Travis</b>	\$1,630.97	\$12,899.03	7	0	3.34
<b>Total</b>	<b>\$6,360.41</b>	<b>\$40,108.05</b>	<b>114</b>	<b>1</b>	
			<b>Fill Rate</b>	<b>99.12%</b>	

**Appendix U — Premarin 0.3 mg Results**

<b>Premarin 0.3 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Barksdale</b>	\$3,826.68	\$10,046.01	147	0	16.96
<b>Beale</b>	\$1,061.51	\$2,556.18	57	0	6.67
<b>Cannon</b>	\$969.54	\$2,832.62	23	0	2.39
<b>Langley</b>	\$2,460.99	\$15,722.26	175	0	20.27
<b>Little Rock</b>	\$1,932.60	\$3,795.10	144	0	16.76
<b>Luke</b>	\$2,929.55	\$20,548.14	236	0	28.67
<b>Scott</b>	\$1,452.05	\$5,670.29	168	0	19.4
<b>Seymour</b>	\$726.02	\$12,117.36	75	0	8.47
<b>Shaw</b>	\$1,414.28	\$13,957.05	118	0	14.08
<b>Total</b>	<b>\$16,773.20</b>	<b>\$87,245.01</b>	<b>1,143</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix V — Premarin 0.625 mg Results**

<b>Premarin 0.625 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Altus</b>	\$722.76	\$12,426.04	35	0	4.1
<b>Barksdale</b>	\$2,607.48	\$13,328.42	331	0	36.71
<b>Langley</b>	\$8,184.86	\$27,240.37	183	0	21.68
<b>Little Rock</b>	\$480.56	\$6,318.22	270	0	32.98
<b>Minot</b>	\$494.72	\$434.55	34	0	3.8
<b>Moody</b>	\$480.56	\$7,055.24	128	0	12.52
<b>Wright Patterson</b>	\$3,305.75	\$9,200.54	284	0	32.78
<b>Total</b>	<b>\$16,276.67</b>	<b>\$76,003.38</b>	<b>1,265</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	



**Appendix W — Premarin 1.25 mg Results**

<b>Premarin 1.25 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Barksdale</b>	\$3,591	\$13,043	140	0	16.58
<b>Columbus</b>	\$2,158	\$7,469	39	0	4.88
<b>Langley</b>	\$5,127	\$9,252	16	0	9.61
<b>Little Rock</b>	\$1,452	\$320	99	0	40.75
<b>Los Angeles</b>	\$2,919	\$4,480	7	0	4.39
<b>Luke</b>	\$2,197	\$15,486	64	0	7.8
<b>Robins</b>	\$726	\$5,660	41	0	5.18
<b>Seymour Johnson</b>	\$4,335	\$10,525	24	0	2.9
<b>Travis</b>	\$4,403	\$15,039	36	0	4.78
<b>Tyndall</b>	\$2,903	\$6,593	32	0	4.01
<b>Total</b>	<b>\$29,810</b>	<b>\$87,867</b>	<b>498</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix X — Prograf 5 mg Results**

<b>Prograf 5 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Lackland</b>	\$11,740.07	\$13,796.89	8	0	4.7
<b>Wright Patterson</b>	\$9,503.63	\$44,340.32	6	0	2.61
<b>Total</b>	<b>\$21,243.69</b>	<b>\$58,137.21</b>	<b>14</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix Y — Sandostatin 30 mg Results**

<b>Sandostatin 30 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Keesler</b>	\$3,913.85	\$11,269.88	9	0	4.18
<b>Lackland</b>	\$0.00	\$12,452.74	2	0	0.93
<b>Total</b>	<b>\$3,913.85</b>	<b>\$23,722.62</b>	<b>11</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix Z — Spiriva 18 mcg Results**

<b>Spiriva 18 mcg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Barksdale</b>	\$2,711.87	\$22,259.02	629	0	89.14
<b>Goodfellow</b>	\$2,770.47	\$3,362.84	137	0	45.59
<b>Los Angeles</b>	\$44.82	\$2,085.01	144	0	52.81
<b>Malmstrom</b>	\$411.39	\$1,191.36	247	2	76.39
<b>Maxwell</b>	\$1,450.25	\$16,035.68	717	2	99.75
<b>Mt Home</b>	\$41.16	\$3,252.01	191	0	55.73
<b>Patrick</b>	\$45.32	\$6,623.57	1185	0	12.81
<b>Robins</b>	\$1,305.60	\$4,505.91	460	2	77.83
<b>Vandenberg</b>	\$493.92	\$1,690.42	156	4	50.28
<b>Wright Patterson</b>	\$398.84	\$12,970.78	1735	1	118.28
<b>Total</b>	<b>\$9,673.62</b>	<b>\$73,976.60</b>	<b>5601</b>	<b>11</b>	
			<b>Fill Rate</b>	<b>99.80%</b>	

**Appendix AA — Tamiflu 75 mg Results**

<b>Tamiflu 75 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Barksdale</b>	\$1,228.76	\$2,554.66	181	6	26.23
<b>Lackland</b>	\$4,546.67	\$16,294.80	294	16	37.06
<b>Langley</b>	\$5,527.35	\$9,218.76	92	0	18.45
<b>McConnell</b>	\$600.00	\$1,087.71	33	0	11.42
<b>Seymour Johnson</b>	\$216.41	\$550.44	18	0	6.27
<b>Sheppard</b>	\$497.72	\$1,401.89	155	41	43.19
<b>Vance</b>	\$415.49	\$1,098.61	12	0	4.53
<b>Total</b>	<b>\$13,032.38</b>	<b>\$32,206.87</b>	<b>785</b>	<b>63</b>	
			<b>Fill Rate</b>	<b>91.97%</b>	

**Appendix AB — Tobradex 5 ml Results**

<b>Tobradex 5ml</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Wright Patterson</b>	\$8,678.88	\$17,024.00	45	0	21.36
<b>Total</b>	<b>\$8,678.88</b>	<b>\$17,024.00</b>	<b>45</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix AC — Votrient 30 mg Results**

<b>Votrient 30 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Travis</b>	\$17,207.21	\$10,357.55	4	0	2.2
<b>Total</b>	<b>\$17,207.21</b>	<b>\$10,357.55</b>	<b>4</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix AD — Vytorin 10 mg Results**

<b>Vytorin 10 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Andrews</b>	\$1,683.18	\$12,108.50	25	0	11.15
<b>Barksdale</b>	\$1,214.87	\$6,199.59	37	0	16.87
<b>Buckley</b>	\$1,306.10	\$7,362.74	21	0	11.94
<b>Columbus</b>	\$457.95	\$1,337.17	4	0	2.79
<b>Langley</b>	\$328.50	\$11,055.92	34	0	15.79
<b>Maxwell</b>	\$437.84	\$1,039.24	250	0	57.58
<b>Mt Home</b>	\$281.06	\$458.98	17	0	10.45
<b>Sheppard</b>	\$1,424.22	\$6,463.78	34	0	11.84
<b>Travis</b>	\$1,153.23	\$14,196.20	119	0	33.16
<b>Total</b>	<b>\$8,286.93</b>	<b>\$60,222.12</b>	<b>541</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	



**Appendix AE — Zemplar 4 mg Results**

<b>Zemplar 4 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Lackland</b>	\$0.00	\$10,159.68	1	0	1.39
<b>Total</b>	<b>\$0.00</b>	<b>\$10,159.68</b>	<b>1</b>	<b>0</b>	
			<b>Fill Rate</b>	<b>100.00%</b>	

**Appendix AF — Zytiga 250 mg Results**

<b>Zytiga 250 mg</b>					
	<b>Savings</b>		<b>1/1/2014 - 9/19/2014</b>		
<b>Base</b>	<b>Annual Expiration</b>	<b>Average On-Hand</b>	<b>Requests</b>	<b>Stockouts</b>	<b>Turnover</b>
<b>Andrews</b>	\$1,952.87	\$15,548.23	14	0	6.5
<b>Travis</b>	\$10,854.72	\$39,530.84	14	3	13.93
<b>Total</b>	<b>\$12,807.59</b>	<b>\$55,079.07</b>	<b>28</b>	<b>3</b>	
			<b>Fill Rate</b>	<b>89.29%</b>	



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14. ABSTRACT A significant challenge facing the Air Force Medical Service (AFMS) Military Treatment Facilities (MTFs) is the perishability costs associated with its pharmaceutical stock. During a two year time period, the AFMS returned expired or nearly expired pharmaceuticals valued at over \$23,000,000. In response to the waste represented by pharmaceutical perishability cost, this thesis analyzes the historical inventory management decisions of 173 MTF/pharmaceutical combinations and proposes an alternative inventory control policy to reduce perishability costs. Based on the critical nature of pharmaceuticals and importance of generating high patient satisfaction, the proposed alternative inventory control system was required to be cognizant of the cost savings/service level trade-off. After applying a fundamental inventory management equation to historical patient demands, the calculated inventory control policy is evaluated against a recent nine month time period of patient demand in terms of potential cost savings and fill rates. At the conclusion of the study, it is determined that the use of the proposed inventory control policy would generate an effective perishability cost savings of approximately \$250,000 annually, as well as a one-time inventory reduction cost savings that exceeds \$1,700,000. In spite of this stock reduction, the studied MTF/pharmaceutical combinations would maintain a strong fill rate that exceeds 99.82%.					
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