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Evaluating the Hazardous Materials (HAZMAT) Pharmacy among Air Force MAJCOMS Using Waste Reductions and Activity Indicators

W. Edward Iseman Jr.

AFIT/GEE/ENV/96D-09

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Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Engineering and Environmental

Management

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Abstract

The increasing emphasis on the environment and the signing of Executive Order 12856 in 1992 have caused the Air Force to dramatically shift toward a pro-active environmental posture. The Hazardous Materials (HazMat) Pharmacy has been designed as an environmentally friendly vehicle to handle, store, dispense, track, recycle and dispose of hazardous materials in the Air Force.

This thesis effort proposes a method in which valuable feedback for the pharmacy can be obtained. Because it is still in the early stages of implementation, there has been little feedback on the pharmacy. An activity index that uses a variable most closely associated with the generation of hazardous waste in a MAJCOM is proposed. Using an aircraft maintenance related variable, like maximum take-off weight, the fluctuations in mission over time can explain a proportion of the reductions over the same time. The additional reductions can then be attributed to pollution prevention efforts, including the HazMat Pharmacy. By comparing the remaining reductions in pharmacy commands to non-pharmacy commands, the difference can be explained by the HazMat Pharmacy. A notional analysis using this technique was conducted in this effort.

Evaluating Hazardous Materials (HazMat)

Pharmacy Among Air Force MAJCOMs

Using Waste Reductions and Activity Indicators

I. Introduction

Background

The Air Force, as a major component of the Department of Defense (DOD), until 1993 had been exempt from most federal, state and local environmental regulations. This exemption was granted primarily with the justification of "protecting national interests." However, as the Cold War came to a close and threats changed, so too did the political climate. Environmental issues continued to receive more and more attention as higher pollution and population increased the burdens imposed on our finite national resources. Ironically, the DOD came to be viewed by some as doing more harm than good for the nation's interests. Specifically, the environment was suffering at many DOD installations due to poor management of environmental resources and potentially harmful waste disposal practices at these bases. Under Executive Order 12856, issued by President Clinton in 1993, all DOD installations are now required to abide by the Emergency

Planning and Community Right-to-Know Act of 1986, the Pollution Prevention Act of 1990, as well as all federal, state and local environmental laws and regulations that apply at that location (Executive Order 12856, 1993). This single executive order has dramatically influenced the way that the DOD conducts its affairs. There was an immediate need to change the attitudes and prevailing practices within the DOD and its components. Moreover, there was an immediate, increased demand for experience and expertise in environmental management throughout the DOD. The AFIT Graduate Engineering and Environmental Management (GEEM) program is one result of this sudden need for environmental expertise on Air Force installations. Numerous other policy and procedural changes have swept across the DOD as a result of the increased emphasis on environmental issues. Military leaders have become acutely aware of the problems that can arise if 'green' laws and regulations are not complied with.

Hazardous materials and the waste generated from their use is one of the biggest areas of environmental concern on Air Force bases. "The single largest waste reduction opportunity in the Air Force is reduction of the large volume of unused hazardous material contributing to the waste stream," according to the Hazardous Materials Pharmacy "How to Guide" (AFCEE 1994). Laws and regulations have very strict requirements on how hazardous materials are handled, stored, used, and disposed. As a result of these requirements, it has become necessary to modify the traditional supply system's process for procuring, storing, allocating, and tracking hazardous materials. The Hazardous Materials (HazMat) Pharmacy has evolved from this need for change.

The HazMat Pharmacy or Cell was designed with the intention that it would serve as the sole, central supply facility responsible for the purchase, storage, distribution, and tracking of hazardous materials on an installation. With one centrally located point through which all hazardous materials must pass, there is a definitive accountability of the HazMat on a base. In the past this was not the case. For example, often times a maintenance worker may need 200 gallons of solvent as soon as possible and would order that solvent through two or three different supply channels, not knowing which one would arrive first. The first to arrive would be used, but the extra orders would be placed on the shelf until needed or until they expired. In many cases, the shelf-life for the hazardous materials did in fact expire. "An Air Combat Command study revealed that 60 percent of their hazardous waste stream was shelf life expired hazardous material. Most of the material had never been opened(AFCEE 1994). Congress and the American public have labeled this sort of waste and inefficiency as unacceptable in the DOD, and rightfully so.

General Issue

Since the implementation of the pharmacy there has been little debate over the potential to substantially enhance Air Force pollution prevention efforts. However, there has been little evidence compiled and analyzed to give concrete evidence regarding the magnitude of benefits obtained from the HazMat pharmacy. This situation is largely due to the fact that HazMat pharmacies have been implemented in only a few bases initially and are still in the early stages of implementation throughout most of the Air Force. Thus, there has been very limited data available to objectively evaluate the pharmacy and its impact. Another reason that feedback has been less than glistening is that there was no specific system of metrics designated to be gathered for feedback other than hazardous waste disposal numbers. Hazardous waste, while acting as an excellent indicator for pollution prevention progress, is not necessarily the best measure of the HazMat pharmacy's effectiveness, especially in its implementation stages. To better understand and estimate the impact that the HazMat pharmacy can have, an index with more hazardous material inputs should be used.

Problem Statement

Although it is believed that HazMat Pharmacies can and have reduced hazardous waste generation through better business practices, no objective, uniform method of determining their effectiveness has yet been developed. Although preliminary economic analyses have been done at specific bases, the models were predictive in nature and have not been verified with actual data. There is little statistical evidence to substantiate the conclusions made in these models. In fact, because the pharmacy concept is such a new one, very little research has been conducted to attempt to evaluate its effectiveness. This research should provide some definitive feedback as to the expected positive impact that newly installed HazMat pharmacies will have on Air Force installations.

Research Objective

The objective of this research is to measure the relative impact of the Hazardous Materials Pharmacy, as the concept is currently being implemented, among operational factors influencing the annual generation of hazardous wastes throughout the Air Force. The pharmacy is still in the early stages of implementation for the majority of the Air Force. Hence, it is quite possible that some of the current installation procedures and practices will be modified as the process matures. Still, there is a basic Air Force concept in place that provides guidance for the framework of a pharmacy implementation at any base. This framework, as it currently exists in several MAJCOMs, will be the basis of this pharmacy evaluation process.

Scope of Research

The HazMat pharmacy concept is currently being implemented or scheduled to be Air Force wide. The pharmacy concept has become the preferred practice for handling, storing, tracking, and disposing of hazardous wastes on Air Force installations. This research is aimed at predicting the overall effect on hazardous waste generation that can reasonably be expected at a MAJCOM level, based upon past full scale implementation of the Hazardous Materials pharmacy. However, the amount of data that is currently accessible and applicable for such an evaluation is quite limited. As the tracking of hazardous materials and wastes becomes better established the effects can be quantified with more confidence.

Need for the Research Effort

The Air Staff in Washington, D.C., has voiced concern over the fact that little or no substantial analysis has been done to validate the HazMat pharmacy. Yet considerable resources are being allocated toward HazMat pharmacy implementation throughout the Air Force. This research effort is conducted with the hope of obtaining corporeal feedback and justification for the allocation of the resources currently being expended on the pharmacy.

Thesis Organization

This thesis research effort is divided into five separate chapters. Each chapter serves a specific purpose. Chapter One has outlined the background and overview of the problem as well as the research objective and scope. Chapter Two is a summary of the literature search efforts and gives a more detailed background and history of the HazMat pharmacy from its inception to its current phase of development. Chapter Three describes the approach and methods used to address the research question. Chapter Four contains the results obtained from the different analytical methods described in chapter three. The final chapter houses the conclusions that are drawn from the research effort as well as areas that require further research efforts. An appendix is also included with calculations and raw data used in the analyses.

II. Literature Review

Overview

The purpose of this chapter is to provide a historical background for how and why the Hazardous Materials Pharmacy has come into being. There has been a specific sequence of documented events that has led to the development and implementation of the pharmacy. From the beginning of the Environmental Revolution in 1970 to the Pollution Prevention Act of 1990, the perspective for Hazardous Materials Management has evolved toward the pharmacy concept. In addition, the specific Air Force interpretation and application of these concepts has evolved as well. The next step that needs to occur in this evolutionary process is a mode of measuring the success of the pharmacy. The use of an environmental activity index as a possible means of evaluating the performance of the HazMat pharmacy, relative to previous supply methods of handling hazardous materials, shall be addressed.

Legislative Background

The general public began to realize that things were not fine and well in the environment around 1970. Isolated incidents, such as "the summer of 1969 when the oily, chocolate-brown Cuyahoga River in Cleveland burst into flames,"(Detwyler, 1971) began opening eyes and getting the public's attention. The passage of the National Environmental Policy Act (NEPA) in 1970 and the formation of the Environmental Protection Agency (EPA) shortly thereafter got the ball rolling.

A major piece of legislation governing solid and hazardous waste, The Resource Conservation and Recovery Act (RCRA), was passed in 1976. This Act was the first piece of legislation to specifically address the generation, handling, storage, transportation, and disposal of hazardous wastes. Even more importantly, the EPA separated hazardous waste as a separate category of solid waste (Tchobanoglous et al. 25). RCRA caused a significant shift in the way that industries viewed the waste generated from production processes. The problem with RCRA was that it focused on treatment and disposal of wastes that were generated. While this end-of-pipe approach toward environmental protection was certainly an improvement over previous practices, it was merely a small step toward true environmental protection. True protection begins at the source, before environmental hazards are even produced.

The promulgation of the Hazardous and Solid Waste Amendments (HSWA) in 1984 provided improved guidance for management of hazardous waste. These RCRA amendments established a basis for bona fide environmental protection. The breakthrough in HSWA was that all generators of hazardous wastes were required to establish a waste minimization program. Waste minimization was the precursor to the EPA hierarchy for pollution prevention, stating that "the elimination or reduction of hazardous waste at the source should take priority over the management of hazardous wastes" (Federal Register, 1993). With HSWA came the concept of waste minimization, and hence, pollution prevention was born.

Pollution Prevention

Pollution prevention is a primary focus of all environmental efforts today, inside and outside of the Air Force. The reason for this emphasis is that it makes good sense. An ounce of prevention is truly worth a pound of cure in the preservation of the environment, where cleanup is usually lengthy and costly, if possible at all. Pollution prevention safeguards the environment and also saves millions of dollars in treatment, compliance, and acquisition costs (EPA, 1993). Here is the national pollution prevention policy, as described in the Pollution Prevention Act of 1990:

> That pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should

> be employed only as a last resort and should be conducted in an environmentally safe manner.

It is critical to note that the Department of Defense was not held directly accountable to this act until the signing of Executive Order 12856 in 1993. At this point the Air Force switched from being a voluntary, sometimes passive participant in community environmental affairs to a mandatory, active one. Air Force environmental stewardship suddenly became a top priority. In a joint memorandum issued to all Air Force MAJCOMs, Secretary of the Air Force Widnall and Chief of Staff, General Fogleman stated:

> Our future commitment to environment, safety, and occupational health (ESOH) programs will not be diminished even in today's challenging budget climate....(These programs) must do more today than ever before, and do it with increased effectiveness. (McCall, 11 Jul 1995).

Air Force leadership, beginning at the top ranks, has realized the importance of environmental protection.

The Air Force has adopted its own concept of pollution prevention as one of its four pillars (cleanup, compliance, conservation, and pollution prevention) in its Environmental Quality Program. It states:

> The Air Force will prevent future pollution by reducing use of hazardous materials and releases of pollutants into the environment to as near zero as feasible. This will be done first through source reduction, e.g. chemical substitution, process change and other techniques. Where environmentally damaging materials must be used, their use will be minimized. When the use of hazardous materials cannot be reused or recycled, dispose of the spent material

and waste as a last resort in an environmentally safe manner, consistent with the requirements of all applicable laws. Environmental costs will be accounted for in computing hazardous material life-cycle costs. (AFPD 32-70, 1994)

It is important to note the precedence or recommended order of preference for the actions in both the Pollution Prevention Act and the Air Force guidance. The preferred order of the approaches for hazardous waste management is called the EPA Hierarchy of Pollution Prevention (source reduction, recycling, treatment, disposal). Reduction at the source is really the only pure form of pollution prevention, while the other three methods of recycling, treatment and disposal are better described as pollution control measures. The HazMat pharmacy directly addresses many of the Air Force objectives for source reduction and recycling as listed in *The Hazardous Waste Management Guide.* For example, in the guide's Waste Minimization Management Options Hierarchy, process changes and improved operating practices are encouraged. The HazMat pharmacy achieves these objectives through inventory control, waste segregation, and established procedures for handling and training.

Furthermore, under the area of recycling in the guide, reuse and reclamation are highly encouraged. With the ability to accept then reissue unused HazMat, and to issue specific job-sized containers, the pharmacy directly addresses this aspect of waste minimization as well. It is obvious that the HazMat pharmacy is geared toward meeting many of the environmental demands affecting the Air Force.

Management Practices of the HazMat Pharmacy

Air Force objectives are naturally the driving force behind the formation of the HazMat pharmacy. However, many management practices that have been successfully applied in private industry can also benefit the Air Force and have been included in the design of the pharmacy. Just-in-time ordering is one critical aspect of the HazMat pharmacy in its effort to reduce large inventories of hazardous materials on bases and the liabilities associated with them. An article in *Hazmat World* reinforces this practice, stating that:

> Reducing the size of a chemical inventory is in step with the widely accepted business practice of just-in-time ordering, and stocking only what is needed in the smallest quantities...fewer chemicals mean less pollution which can yield a "green dividend" of lower costs (Nielsen, May 1994).

This new approach to hazardous materials management is a drastic change from the traditional supply system previously used. The old Air Force system of supply was geared toward mission accomplishment and was very effective in many ways. However, in the area of environmental protection the system was severely lacking. Redundant supply channels were available for personnel to obtain hazardous materials and little or no tracking coordination existed between them. This made for a serious lack of accountability of HazMat on installations.

Accountability not only can save money for the Air Force, but it is mandated by law under the Toxic Release Inventory (TRI) reporting that now applies to the DOD under Executive Order 12856. HazMat Pharmacies are providing accountability for materials via a central computer system that tracks and monitors all hazardous materials entering and exiting the pharmacy. Environmental Management Information System (EMIS) is the name of the main materials management system being implemented throughout the Air Force. The EMIS computer system provides data on quantities and types of hazardous materials issued, as well as the units authorized to receive them on a base. Air Force Materiel Command (AFMC) was the first command to begin pharmacy implementation and has its own system, the Hazardous Materials Management System (HMMS), that it still uses. Both EMIS and HMMS are scheduled to be replaced in the near future by another system that has been approved for installation across the entire DOD. This system is called the Hazardous Substance Material System (HSMS) and is supposed to incorporate HMMS functions as well as some EMIS capabilities. However, several delays have been encountered in the programming phases of HSMS and it is yet to be implemented.

The old, redundant supply channels also led to excessive inventories in many shops. These inventories lead to extra waste and, as mentioned in the ACC example in Chapter One, hazardous waste disposal is a major problem. "Poor inventory control practices can create three major sources of waste: excess materials; out-of-date, expired, or out-of-specification materials; and materials that are no longer needed or used" (McComas, 1995). These are the areas, especially expired materials, where the Air Force has the greatest potential for improvement. The improved management practices of the pharmacy should help solve many of these problems for the Air Force. McComas also illustrates how poor inventory control:

> creates additional, indirect costs because it increases the need for storage or floor space, which in turn can reduce production area; increases disposal costs; and worsens the risk of spills because holding materials longer leads to more handling, and the integrity of the packaging declines with age (McComas, 1995).

The pharmacy was designed with the intent of providing the Air Force substantial savings through effective inventory management of hazardous materials.

Current Air Force HazMat Pharmacy Evaluation

The Hazardous Materials Pharmacy certainly seems to be a wonderful concept in theory. However, the current dilemma is how to determine if it is actually performing its intended objectives. The method that is currently used to provide feedback on the HazMat pharmacy at the Air Staff is an actual quantity change in pounds of hazardous waste disposed of annually across the MAJCOMs (Nelson, May 1996). The actual quantity change method does not take into account the difficulties of implementing a given source reduction activity, reductions in toxicity, or changes in production efficiency or levels (Baker et all., 1991 5). Readily available data to track the reductions in hazardous waste across major commands has been compiled and submitted, in response to Air Force Instruction 32-7080 *Pollution Prevention Program.* Pollution Prevention literature indicates that effective inventory control practices should indeed lead to reductions in the waste stream. The expectation was that MAJCOMs which are fully or almost fully implemented with HazMat pharmacies should be experiencing greater reductions in hazardous waste than MAJCOMs that have yet to implement them. However, this was not the case when raw data on hazardous waste disposal reductions were compared (see Appendix A). The MAJCOMs with pharmacies fully or mostly implemented (ACC, AFMC, AMC) did not experience greater apparent reductions than some MAJCOMs that had yet to implement pharmacies (AETC, ANG, AFRES). Thus, it appears that either the HazMat pharmacy has not realized significant returns, or the hazardous waste metric for evaluating the pharmacy is an insufficient feedback measure. The research hypothesis here is that the latter scenario has occurred.

Regression Modeling

Simple linear regression modeling will allow for the development of a prediction of the mean value of a specific response variable based upon another, predictor variable. It must be noted that "no matter how strong the statistical relationship, no cause and effect pattern is necessarily implied by the regression model" (Neter et al., 1989:29). However, the assumption that hazardous waste is generated on installations by the daily activities associated with the primary mission of the base is reasonable. So, for this analysis assigned personnel will be used in a simple regression analysis model, with hazardous waste as the response variable, to try and establish a relationship between the amount of hazardous waste generated on Air Force installations and selected indicators of activity.

The regression analysis equation that will be used is shown here:

$$Y_i = \beta_o + \beta_1 * x_i + \epsilon_i \qquad i=1\ldots n$$

where

Y_i = response variable, hazardous waste disposal

β_0 = the y-intercept

β_1 = the slope of the regression line

x_i = predictor variable, assigned personnel

ϵ_i = error ~ $N(0,\sigma^2)$ i.i.d.

The coefficient of determination, or r^2, is "the proportion of observed Y variation that can be explained by the simple linear regression model" (Devore, 1995: 489). A value of r^2 equal to .85 indicates that 85 percent of the variation in the dependent variable can be accounted for by the approximate linear relationship between the independent and dependent variable. A large coefficient of determination is desired when determining the amount of waste per capita.

Activity Index Method for Evaluating HazMat Pharmacy

An activity index method was chosen for this research analysis instead of a production ratio that is often used. "An activity index is based on a variable (other than production) that has the primary influence on the quantities of the toxic chemical recycled, used for energy recovery, treated or disposed" (Greiner 1995, 65).

An activity index method for evaluating the HazMat pharmacy would account for changes in MAJCOM activities that may cause waste levels to fluctuate. Over a specified time period, the ratio of activity levels is used to form an index. The activity index is the ratio of activity levels between the current year and the baseline year. The formulas that will be used to calculate the adjusted change in quantities are:

$$\text{Activity Index} = \frac{\text{Activity Level Current Year}}{\text{Activity Level Baseline Year}}$$

$$\text{Adjusted Change in Quantity} = \frac{\text{(Current Quantity-(Baseline Quan*Activity Index)}}{\text{Baseline Quan * Activity Index}}*100$$

An activity index method of analysis has four key assumptions. These are: that waste generation and the activity level are linearly related, no fixed quantities of waste are generated independently of activity levels, no factors other than the activity levels and waste reduction efforts (HazMat pharmacy) affect the quantity of waste generated, and the measures of activity and waste disposal are consistent over time (Baker et al., 1991:5).

The assumption that no quantities of waste are generated independently of activity levels is logical. The majority of waste in commands will be attributed to the maintenance related variables where applicable, while the personnel activity level is the a baseline indicator applicable at all commands.

The third assumption that factors other than activity levels and pollution prevention efforts affect the quantity of waste generated is not necessarily realized. Changes in laws and regulations often influence the amount of waste generated on installations over time and cannot realistically be accounted for in this research effort. However, each MAJCOM should generally be affected in the same ways from federal regulations, leaving only state and local changes as unknowns.

The last assumption that waste disposal and activity levels are consistent over the specified time period is a required assumption. All indications of the data compiled for this effort lead to the belief that it is consistent over the specified time periods.

III. Research Methodology

This section of the thesis effort focuses on the data requirements in addition to the methodology that will be utilized to address the research question. The research objective of this effort was to evaluate the hazardous material pharmacy among the MAJCOMs using reductions in hazardous waste and activity level indicators. An activity index was used to encompass these indicators in a normalized method of analysis.

General Methodology

This section describes the methods utilized to try and evaluate the pharmacy in a normalized fashion. As mentioned in Chapter Two, an activity index was chosen over a production ratio. For the Air Force this method is more applicable than a productivity ratio because it is extremely hard to define and quantify an Air Force 'product.' National Defense is the primary goal or product of the Air Force but this is a very intangible term. Aircraft sorties was considered a reasonable production ratio but the difference between the number of sorties and actual aircraft in service is insignificant. Thus an activity index using aircraft maintenance related variables and assigned personnel was adopted.

The major Air Force activity associated with HazMat use and waste generation is aircraft maintenance. It is recognized that aircraft maintenance activities are the biggest users and generators of HazMat on a typical Air Force installation. An AETC pollution prevention study on the largest contributors to the hazardous waste stream found nine of the top ten wastes generated in the command were aircraft related (Davis 17 OCT 1996). Hence, aircraft related variables will be the main activities assessed.

<u>Actual Quantity Changes Can be Misleading</u>

Simply using waste reductions probably does not effectively indicate pharmacy success because stockpiles must be eradicated when the pharmacy is installed on an installation. Excess stockpiles of HazMat are gathered on "amnesty days" where shops and offices may turn any quantity of hazardous materials or wastes with impunity. Amnesty collections allow the pharmacy to begin establishing its database accountability, but also tends to create a spike in the waste stream. Thus, hazardous waste disposal numbers are generally inflated during the pharmacy implementation phase for a MAJCOM. This can lead to incorrect conclusions to be drawn when evaluating the pharmacy with an actual quantity change type system.

It is possible that the amnesty days have produced spikes in the waste stream while increasing the inventories in pharmacies and therefore reducing subsequent purchases. Thus by factoring in an indicator of purchases made by a pharmacy, a better overall picture of its impact could be obtained.

The amounts of HazMat entering a base or pharmacy would be the ideal parameters for evaluating the pharmacy's effectiveness. A box model constructed with valid outputs (hazardous waste) and inputs (HazMat purchased) would allow for specific analysis of the impacts attributable to the HazMat pharmacy. Unfortunately, input data on base level or MAJCOM level purchases of hazardous materials was not available. In fact, accountability for hazardous material purchases, or lack thereof, is one of the main issues the pharmacy concept was designed to address. Thus, the activity indexing method of evaluating the pharmacy, while not ideal, should allow for more objective comparisons between the MAJCOMs and a better evaluation of the HazMat pharmacy's performance to date.

Using the number of aircraft and aircraft related parameters, the index will help to account for possible changes in mission or force structure within a command. This way comparisons across different commands can be made in a more impartial manner.

Furthermore, the use of MAJCOM assigned personnel will be factored into the index. The reason for the inclusion of this additional parameter is to represent the unique MAJCOMs that have primary missions other than flying operations. For instance, Air Force Materiel Command (AFMC) and Air Force Space Command (AFSPC) do not have active flying missions associated with their day to day operations. Thus, a variable that exists in all commands needed to be included to help normalize the different missions of the MAJCOMs.

For actual personnel assigned to the command, civilians as well as military will be included. This should give a better overall indication of the total active workforce that is actually contributing to the with hazardous waste stream on an installation. Moreover, in the downsizing and streamlining that is prevalent throughout the DOD, use of contractors and civil service employees is on the rise. This trend is most prevalent in non-combat commands, such as Air Education and Training Command (AETC) where squadrons such as Civil Engineering are being contracted out due to a lack of a mobility requirement.

Activity Index Methodology

In this process the initial step was to determine if a statistical association exists between the amount of hazardous waste produced at the MAJCOMs and the chosen activity variables. An attempt was made to see if a correlation exists between hazardous waste disposal and the numbers of people assigned, and primary aircraft assigned to each MAJCOM. Both base personnel and aircraft related parameters were considered to be good overall indicators of activity levels occurring at Air Force installations (Nelson 16 May 1996). A strong correlation in all commands would be the perfect result but, due to the variability between the commands and scarcity of data, it was not expected that a strong correlation would occur in all cases.

To better equilibrate the numerous differences that exist between the MAJCOMs additional variables were considered. The next objective was to devise a method to more critically and objectively evaluate HazMat pharmacy performance among the MAJCOMs. It was decided that primary assigned aircraft (PAA) would be broken down into more specific elements that differentiate the various aircraft types found within the MAJCOMs. The parameters chosen were number of engines and the maximum take-off weight (lbs) of the aircraft. These aircraft specific parameters were expected to provide a much better indication of activity levels than just the raw number of airframes. These parameters are better suited to take into account the relative size of the aircraft and the amount of associated maintenance activities that should occur. The Air Force has a broad range of aircraft in the inventory, and assuming that a C-141 cargo plane generates the same amount of hazardous waste as a T-37 trainer is probably not realistic.

Thus, the primary assigned aircraft were categorized into different classes of comparable aircraft expected to generate similar quantities of hazardous materials and wastes.

Normalization is a method where each MAJCOM should be classified on a more level field according to its personnel and the types and numbers of aircraft. With normalization, the fluctuations in base activity over time should be factored out of the picture so that the reductions due to other causes, the HazMat pharmacy for example, can be seen more clearly. However, AFMC and AFSPC, lacking an appreciable amount of assigned aircraft, do not fit into the mix very well. These commands are exceptions that cannot be measured in the same ways as the flying commands. The population variable is the only applicable one for these commands and another representative variable, such as engines serviced (AFMC) or operational missiles/satellites (AFSPC), must be used for these two exceptions.

Data Collection

This section outlines the data collection methods that were utilized to gather the necessary data for analysis. It is of great importance to note that the amount of data readily available and specifically applicable to the research effort was extremely limited. A combination of factors, stemming from the newness of the pharmacy to the lack of hazardous materials tracking due to Air Force practices established prior to Executive Order 12856 (1993), made reliable, comprehensive hazardous material data across the MAJCOMs impossible to compile.

Unfortunately hazardous material inputs into the pharmacies or installations as a whole, the best suited data for an evaluation, were not retrievable. The author exhausted a plethora of channels in attempts to acquire such data, from the base level up to MAJCOMs and the Air Staff, with only minimal success. In the few circumstances where quality data actually existed, there was simply no standardization among the different installations that would allow for an unbiased analysis to be conducted. However, there was some reliable and available data that was successfully compiled and analyzed.

Hazardous Waste Disposal Data. As mentioned in Chapter One, the previous method for evaluating the performance of the HazMat pharmacy was an actual quantity change in hazardous waste reductions in each MAJCOM over time, based upon a 1992 baseline. This data, hazardous waste disposal in pounds across the MAJCOMs, was obtained from the Air Staff and used as the foundation of this research. Hence, the assertion of this research is not that this data is a poor indication of pharmacy performance. Instead, it is suggested that a better, more comprehensive measure could be made with an index of hazardous waste reductions that includes activity indicators. The hazardous waste disposal numbers for each MAJCOM were submitted by the individual MAJCOMs to the Air Staff and are assumed to be of good precision.

Assigned Personnel and Primary Assigned Aircraft. Initial data gathered was the number of primary assigned aircraft and the total number of personnel assigned per MAJCOM. This data was obtained from the *Air Force Magazine* which publishes an almanac in May of every year. Air Force Magazine is a publication specifically designed to serve the Air Force and its members and the almanac edition charts key Air Force and DOD figures from the previous year. The data collected was based on calendar year values which match the hazardous waste disposal data. While the numbers themselves may not be exact, they are very consistent indicators of activity trends and provide close resource estimates based upon unclassified data obtained from "the Secretary of the Air Force Office of Public Affairs in its role as liaison with Air Staff agencies" (AF Magazine May 1996).

Aircraft Engines and Maximum Take-off Weight. Once the numbers and types of aircraft present in the Air Force were gathered from the almanac, data for the number of engines in each aircraft was obtained from *Jane's Aircraft of the World* and *The Military Aircraft of the World* by William Green and

Gordon Swanborough. This data was compiled for all but a handful of the aircraft in the Air Force inventory with greater than 97 percent of the total aircraft accounted for. The planes were then classified in categories according to their mission. The categories included: bombers, fighter/attack, refuelers, cargo/transport, reconnaissance, helicopters, special operations, mobility, trainers, and aeromedical aircraft. Each category contains planes that are very similar in mission, size, and capability. Within these specific categories, a focus of planes from the applicable categories can be assigned to each command. Table one shows the categories of planes along with the types and numbers of specific aircraft included in those categories. The percentage of all planes in the inventory that are actually included in that category is also shown.

Table 1

Bombers	B-1 B-2 B-52
Cargo/Transport	C-5 C-12 C-17 C-21 C-130 C-141
Electronic Warfare	F-4G EF-111
Fighter/Attack	A-10 F-15 F-16 F-111 F-117
Helicopter	HH/UH-1 HH-60 TH-53
Reconnaissance	E-3 WC/EC/OC/RC-135 U-2 EC-130
Special Operations	C-130 CH-53 UH-60
Tanker	HC-130 KC-10 KC-135
Trainer	T-1 T-3 T-37 T-38

Categories of USAF aircraft and specific planes included in each category

Analytical Tools

Correlation. For a given sample the correlation coefficient r is a measure of how strongly related two variables are in a given sample. (Devore 1995: 510). If a variable has a large value that corresponds to a large value of another variable then r will be positive. Similarly, if a large value for a variable corresponds with a small value for another variable then r will have a negative value. The range over which r values may occur is from -1 to 1 depending on how strong two different variables are associated with one another, and if their relationship is positive or negative (Devore 1995:510). Devore defines a correlation as strong if $0.8 \leq |r| \leq 1.0$, weak if $0.0 \leq |r| \leq 0.5$ and moderate otherwise (1995:512).

Box and Whisker Plot. The box and whiskers plot or boxplot, as it is sometimes called, is a tool used to describe a data set. The plot consists of a box that has a line drawn through at the median. The ends of the box are the upper and lower fourths. These fourths are the median of the smallest (lower fourth) and largest (upper fourth) $n/2$ observations if n is even and $n/2 + 1$ if n is odd (Devore 34). The fourth spread, f_s, is the upper fourth minus the lower fourth. Tails are drawn from the box out to the farthest observation still within $1.5*f_s$. Outliers are denoted on the graph by an open circle if they are mild, $\leq$

$3.0*f_s$, and a solid circle if they are extreme, $\geq 3.0*f_s$ (Devore 34). In summary, the boxplot gives illustrate four main points about a data set: the center, the spread, the departure from symmetry, and the identification of outliers (Devore 33).

IV. Data Analysis and Findings

Overview

This section of the research effort reports the data analysis that was summarized in Chapter Three. The main objective of this research effort was to try to evaluate the Hazardous Material Pharmacy at the MAJCOM level using hazardous waste reductions and the best available activity indicators. Two different types of activity indicators were first considered, total assigned personnel and primary assigned aircraft, within the MAJCOMs. Additional aircraft indicators that were considered were the number of total engines (per MAJCOM), maximum take-off weight, empty gross aircraft weight, and maximum internal fuel weight (of assigned aircraft) in pounds. Each activity indicator was evaluated over calendar years 1992 through 1995 across the applicable commands. The objective was to find the indicator that shows the best linear association with hazardous waste generation and will use it as an activity indicator for the best overall evaluation of the HazMat pharmacy.

Analysis of Potential Activity Indicators

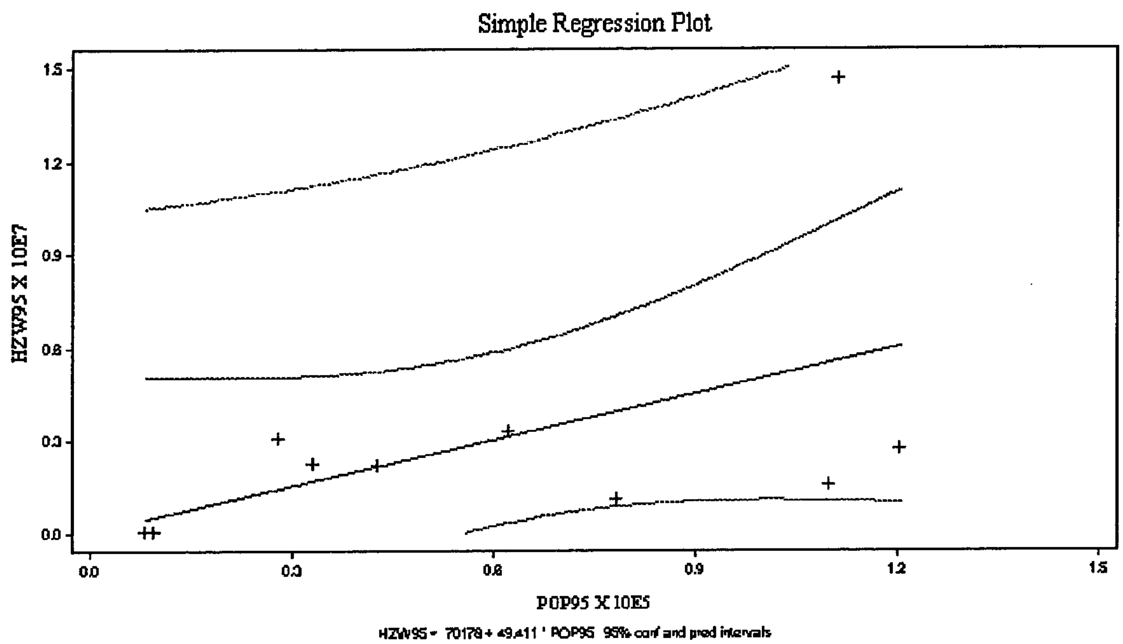
An analysis of every available activity indicator was conducted to try and determine the one best suited for a pharmacy analysis. The hypothesis is that no single variable will be a perfect linear fit for the hazardous waste generated across the MAJCOMs. However, it is expected that some variables will be generally outperform the others and could serve as adequate indicators of activity throughout the Air Force. If no single variable meets the requirements then possibly some combination of the variables may act as a good indicator and will be considered.

Total Personnel Assigned. The total number of assigned personnel was the first activity indicator considered. This variable is one that easily applies to every command and is a logical indicator of the amount of activity that occurs within the command. While it is reasonable to say that the number of assigned personnel may be an adequate predictor of hazardous waste generated on an installation, the variability is expected to be high with such a variable because so many other factors go into the number of people on a base.

The simple linear regression plot of 1995 assigned personnel versus hazardous waste for 95 is shown in Figure One. The inside arcs around the regression line are the 95 percent confidence intervals and the outside arcs (only top arc visible) are the 95 percent prediction intervals. All of the commands fall within the confidence intervals except for AFMC which is still within the prediction interval. However, the coefficient of determination, r^2, is 0.2511 indicating that there is substantial variability between the commands. The results for calendar years 92-94 are all similar with MAJCOMs falling on or inside the confidence interval and AFMC being the exception in each year.

Figure 1

Simple regression plot with hazardous waste disposal as the dependent variable and assigned personnel as the independent variable

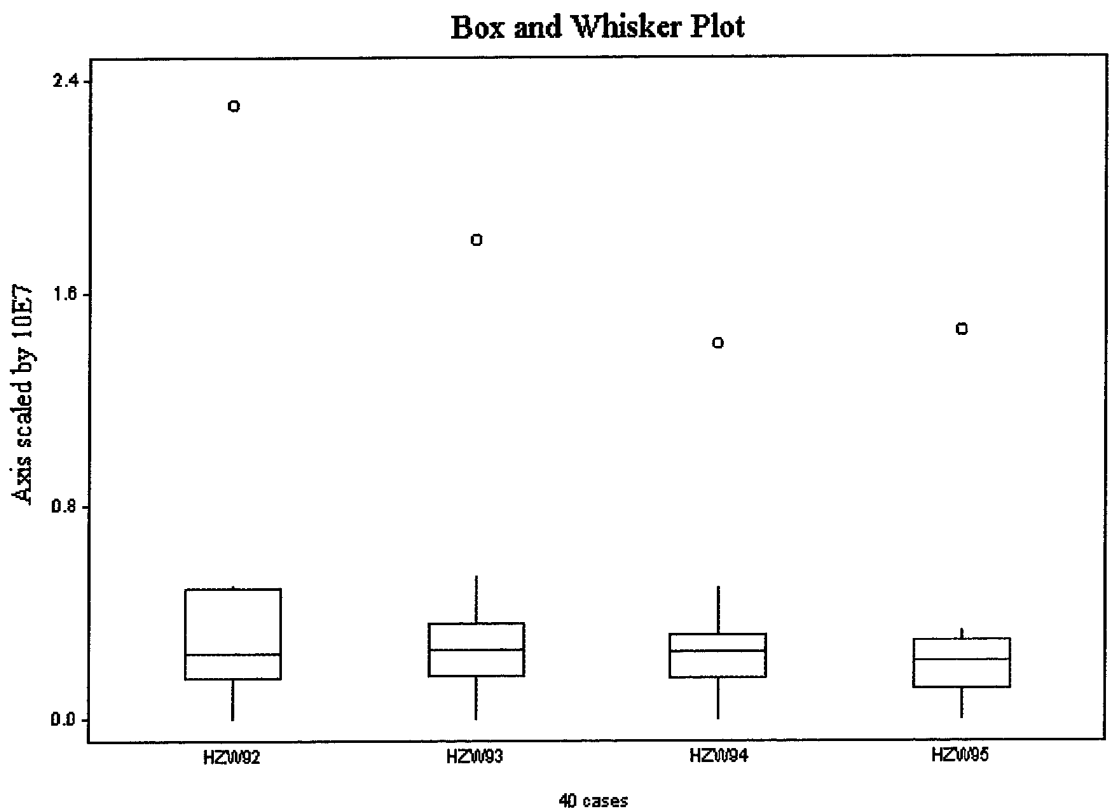


The fact that AFMC is an outlier does not really come as a surprise. Due to the highly industrial focus of the mission, AFMC generates substantially more hazardous waste than any other MAJCOM. The higher hazardous waste generated per person is directly due to the large industrial maintenance shops and logistics centers that exist in AFMC.

Box and whiskers plots of the hazardous waste disposal by MAJCOM, shown in Figure Two, demonstrate that AFMC is indeed a mild outlier, indicated by the hollow circle. The reduction trend of AFMC can also be seen clearly with these plots as that command clearly moves toward the box group of other commands from 1992 to 1995.

Figure 2

Boxplot of hazardous waste disposal numbers across the MAJCOMs from 1992-1995



The correlation coefficients for the number of assigned personnel are given in Table Two.

Table 2

Correlation Coefficients and two-tailed p-value between Hazardous Waste Disposal and Assigned Personnel

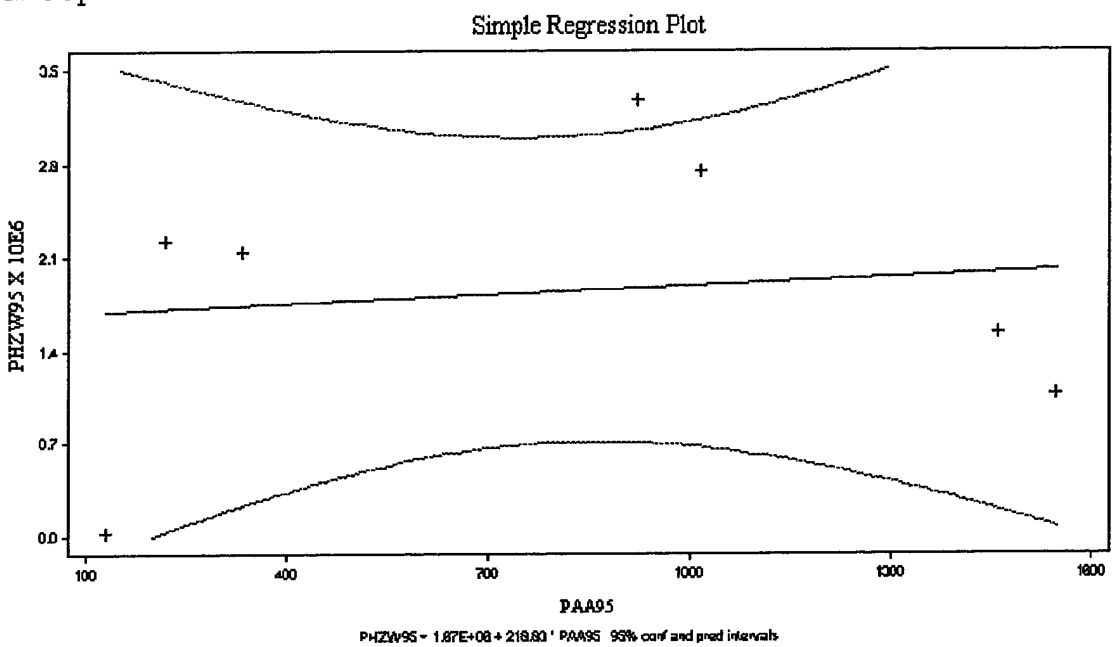
	1992	1993	1994	1995
r	0.4736	0.5726	0.6267	0.5011
p	0.1667	0.0836	0.0525	0.1401

These coefficients are not that strong but, they are all positive and moderate ($0.5 \leq r \leq 0.8$) or close to moderate, indicating that conceivably personnel could be a viable measure of activity. None however, are statistically significant at the .01 level as evidenced by the two-tailed p-values.

Aircraft Related Variables. As stated earlier, aircraft are a critical component of the Air Force and the aircraft maintenance activities are recognized as the primary generators of hazardous waste on bases. The variable first considered was the raw number of primary assigned aircraft (PAA) per command. The simple regression plot of primary assigned aircraft and hazardous waste disposal for 1995 is shown in Figure Three. All but one of the commands fall into the 95 percent confidence interval, but the interval is a very wide one. The low amount of explained variance is indicated by the r^2 value which is only 0.014. Only seven commands are plotted versus the ten for personnel due to differences in mission (i.e. AFSPC, USAFA, AFMC have insignificant numbers of aircraft). The other years had similarly dismal results with 1992 having the best fit but an r^2 still only equal to 0.447.

Figure 3

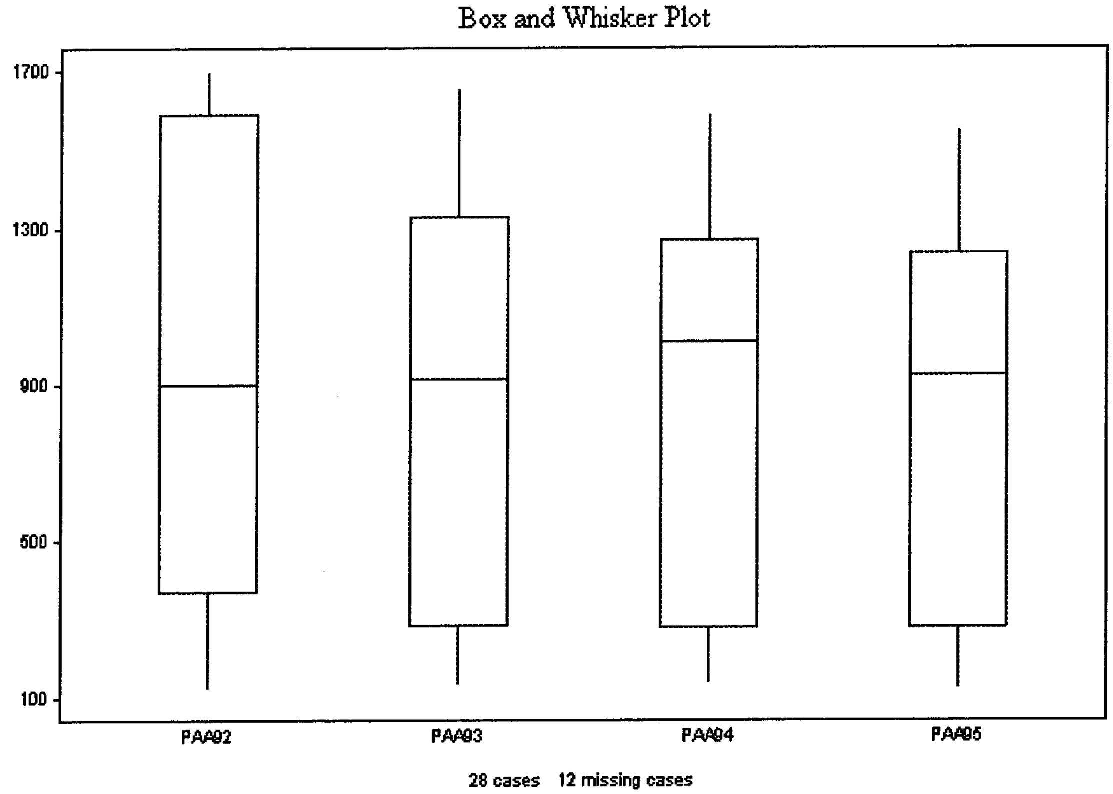
Simple regression plot with hazardous waste disposal as the dependent variable and primary assigned aircraft as the independent variable



A box and whiskers plot of the primary assigned aircraft can be seen in Figure Four. There are not any mild or extreme outliers in any given year. However, all of the commands are not included because of the aforementioned mission differences. The commands that are not included would be best represented by a variable specific to that command. For the AFMC Air Logistics Centers, a former student, Edward Finke, used several different variables in a similar activity index method. The variables used included the number of engines serviced, the total number of man-hours related to aircraft related maintenance (DPAHs) and the number of missiles serviced (Finke, 1994).

Figure 4

Boxplot of Primary Assigned Aircraft (PAA) across applicable commands



The correlation coefficients for primary assigned aircraft and hazardous waste disposal are given in Table Three. The correlation is weak in each year except 1992 (moderate) indicating that use of PAA numbers alone is perhaps a poor candidate to predict hazardous waste disposal at MAJCOMs. The two-tailed p-values, obtained from Statistix software package, also does not suport that there is statistical significance between the variables.

Table 3

The correlation coefficients and two tailed p-values between hazardous waste disposal and primary assigned aircraft for the indicated calendar years

	1992	1993	1994	1995
r	0.6688	0.2066	0.3571	0.1185
p	0.1005	0.6567	0.4317	0.8002

Categorization of Aircraft Data. The next step for analyzing the aircraft related variables was to break down the Air Force inventory into specific aircraft categories composed of similar planes. Once the types of aircraft were organized into categories, the number of each particular aircraft in the inventory was found and summed for each category. From these numbers a ratio of types of aircraft was determined within each category. This ratio was then applied to the number of engines found on that aircraft and also the maximum take-off weight of that aircraft. An overall weighted average for the number of engines and maximum take-off weight was then established for each category of aircraft. Figure Five illustrates how these values were compiled on Excel® spreadsheet. Similar calculations were performed for every other category of aircraft mentioned, based upon 1995 Air Force inventory, and can be found in Appendix B.

Figure 5

		# in		Empty	Fuel Cap	Max T.O.
BOMBERS		**inventory**	**Engines**	**weight (pounds)**		
	B-1	84	4	115,000	155,000	400,000
	B-2	14	4	105,000	190,000	400,000
	B-52	85	8	172,800	150,000	488,000
	Total	183				
AVG NUMBER OF ENGINES			**5.858**			
	AVERAGE EMPTY GROSS WT.			**141,082**		
	AVERAGE FUEL CAPACITY (lbs)				**155,355**	
		AVERAGE MAXIMUM T.O. WT. (lbs)				**440,874**

Weighted average values for engines, gross wt., fuel capacity, and max take-off weight for bomber aircraft.

Next, the individual aircraft within each MAJCOM were broken down into all of the applicable categories. The total number of MAJCOM aircraft in a category were multiplied by the Air Force average for that category and then totaled for every category within the command. The resulting information gives the number of engines, maximum take-off weight and other parameters based on the quantity of each category of aircraft in the command for a given year. The 1995 calculations for Air Education and Training Command are shown in Figure Six. The other commands can be viewed in Appendix C.

Figure 6

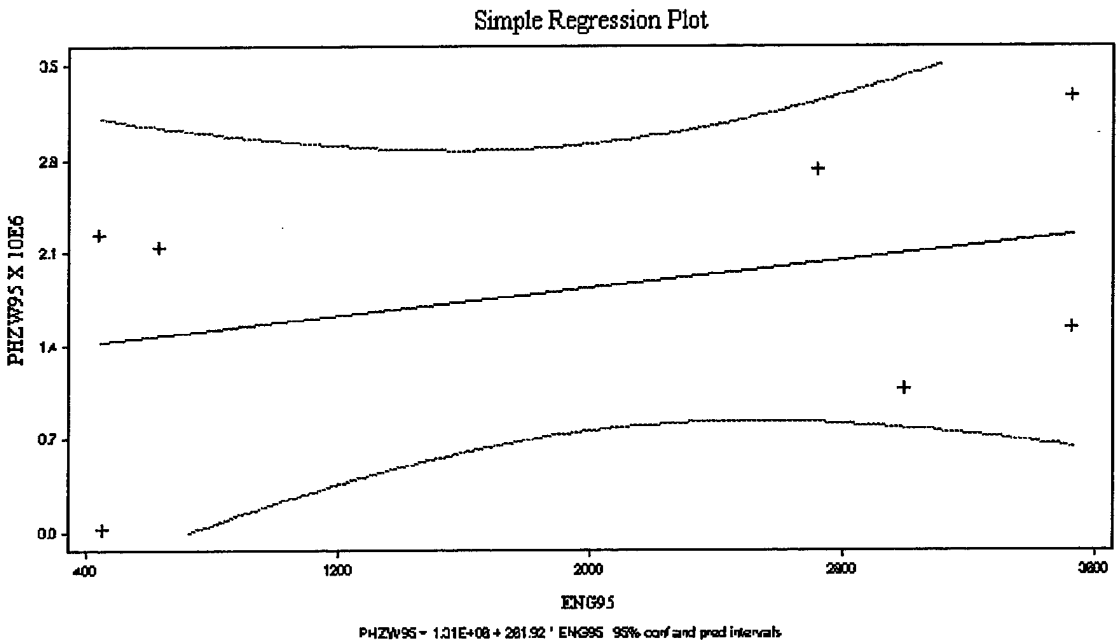
1995 AETC AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF TRAINERS (T-1,3,37,38) =				1,159			
			Engines	1.917		Te =	2,221.8
			Gross wt	5,943		Tg =	6.89E+06
			Fuel	2,742		Tf =	3.18E+06
			Max TO wt	9,472		Tt =	1.10E+07
NUMBER OF FIGHTERS (F-15,16) =				279			
			Engines	1.566		Fe =	436.9
			Gross wt	25,595		Fg =	7.14E+06
			Fuel	10,061		Ff =	2.81E+06
			Max TO wt	54,865		Ft =	1.53E+07
NUMBER OF TRANSPORTS & TANKERS				84			
			Engines	3.604		Ce =	302.7
			Gross wt	130,409		Cg =	1.10E+07
			Fuel	95,566		Cf =	8.03E+06
			Max TO wt	281,652		Ct =	2.37E+07
NUMBER OF HELICOPTERS =				27			
			Engines	1.438		He =	38.8
			Gross wt	9,723		Hg =	262,521
			Fuel	2,803		Hf =	75,681
			Max TO wt	17,388		Ht =	469,476
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total	
3000		2.52E+07		1.41E+07		5.04E+07	
TOTAL AIRCRAFT =		1,549					

<u>Engines as Activity Indicator</u>. The number of PAA-installed engines in a command was explored as a possible indicator of activity levels within a command. The total number of engines was computed using the method described above. This parameter in relation to the amount of hazardous waste generated in the command was then analyzed. A simple linear regression plot of the number of engines in

service per command versus the hazardous waste disposed of in the same command is given in Figure Seven.

Figure 7

Simple regression plot with hazardous waste disposal as the dependent variable and number of PAA-installed engines as the independent variable



The r^2 value for this regression model was 0.1253 inferring a low degree of explained variability in 1995. However, for 1992 data the r^2 value was 0.7234 which is much better.

The correlation between engines and the hazardous waste disposed of from 1992 through 1995 is in Table Four.

Table 4

The correlation coefficients and two tailed p-values between hazardous waste disposal and engines.

	1992	1993	1994	1995
r	0.8505	0.3090	0.5093	0.3540
p	0.0153	0.5001	0.2430	0.4360

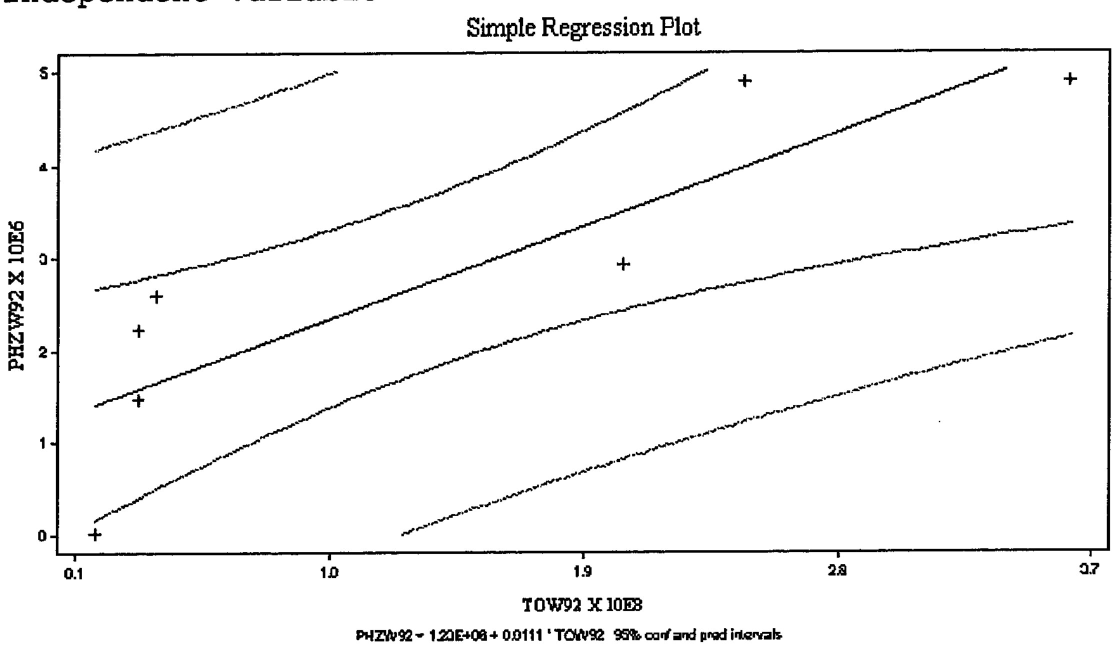
The engine variable covers a fairly wide range of correlation coefficients, from 0.3 - 0.85. The performance of this variable as an indicator of activity levels across the applicable MAJCOMs is questionable, but definitely not an impossibility based on this data. Due to this uncertainty, more complete data needs to be analyzed before it can confidently be determined that this is a suitable variable.

Maximum Take-off Weight. The maximum take-off weight was another variable considered as an activity indicator. The maximum take-off weight is an aircraft performance characteristic that is available in specification data for practically every airplane in the world. It also gives an excellent suggestion toward the size of the plane. A bigger plane will have a larger maximum take-off weight and it is reasonable to suppose that a larger plane would have a greater amount of hazardous waste generated from its maintenance (painting, cleaning, etc.). A simple regression analysis plot of maximum take-off weight as the independent variable and hazardous waste as the dependent variable for

1992 is displayed in Figure Eight. The plot is not a bad fit, with all points but one within the 95 percent confidence interval and an r^2 value of 0.7543 which is very encouraging. However, as with the engine variable, both the r^2 value and regression fit were less favorable in the other three time periods.

Figure 8

Simple regression plot with hazardous waste disposal as the dependent variable and maximum take-off weight as the independent variable



The correlation coefficients and corresponding p-values from 1992 through 1995 for maximum take-off weight are given in Table Five. These correlation coefficients are all moderate to strong and but the p-values indicate no statistical significance. Still, the 1992 p-value is very close to a statistically significant value of 0.01 and maximum take-off weight deserves serious consideration as an activity indicator.

Table 5

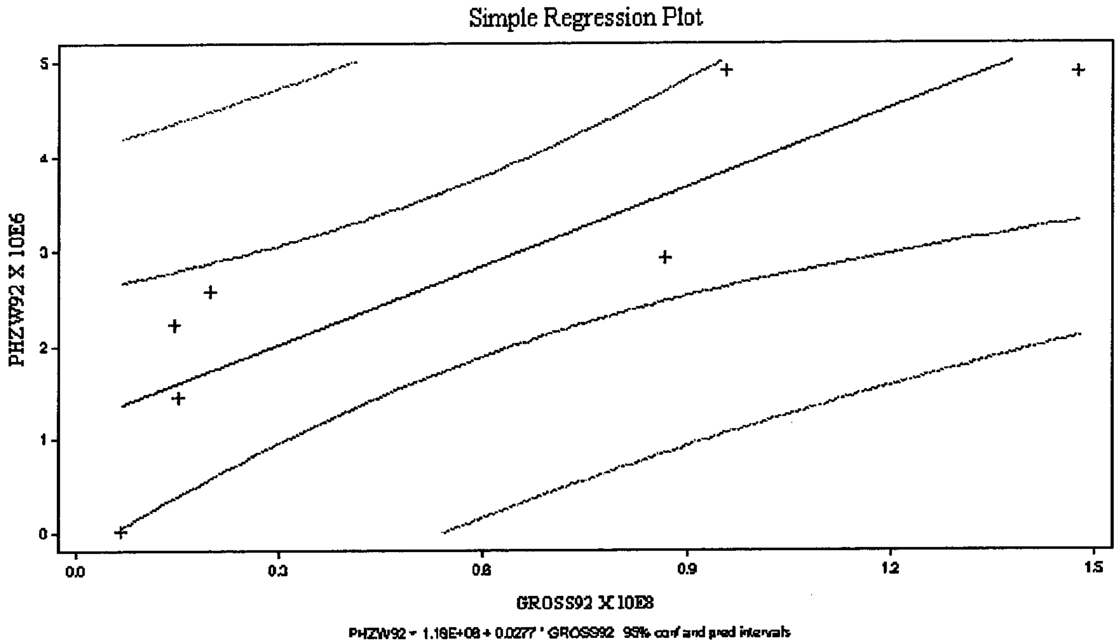
Correlation coefficients and two tailed p-values between maximum take-off weight and hazardous waste

	1992	1993	1994	1995
r	0.8685	0.5144	0.5579	0.6304
p	0.0112	0.2375	0.1931	0.1291

Empty Gross Aircraft Weight. The empty gross weight of the aircraft was the next activity level candidate to be analyzed. The empty gross aircraft weight is how much an aircraft weighs sitting on the runway completely empty with no fuel or cargo. This variable also should do well in distinguishing between the size and mass of different aircraft and their consequent wastes. The simple regression plot with 1992 values of empty gross weight as the independent variable is shown in Figure Nine.

Figure 9

Simple regression plot with hazardous waste disposal as the dependent variable and empty gross aircraft weight as the independent variable



The fit for the regression line from 1992 using empty gross weight of aircraft is a pretty good one. The points are in an fairly linear pattern and have a fairly high explained variation as indicated by an r^2 of 0.7463. The 1992 data had the best fit of any year. The correlation coefficients and p-values for all four years can be seen in Table Six. The correlation coefficient values are all very encouraging with but still not quite statistically significant at a .01 level, given by the p-values.

Table 6
Correlation coefficients and two-tailed p-values for empty gross weight

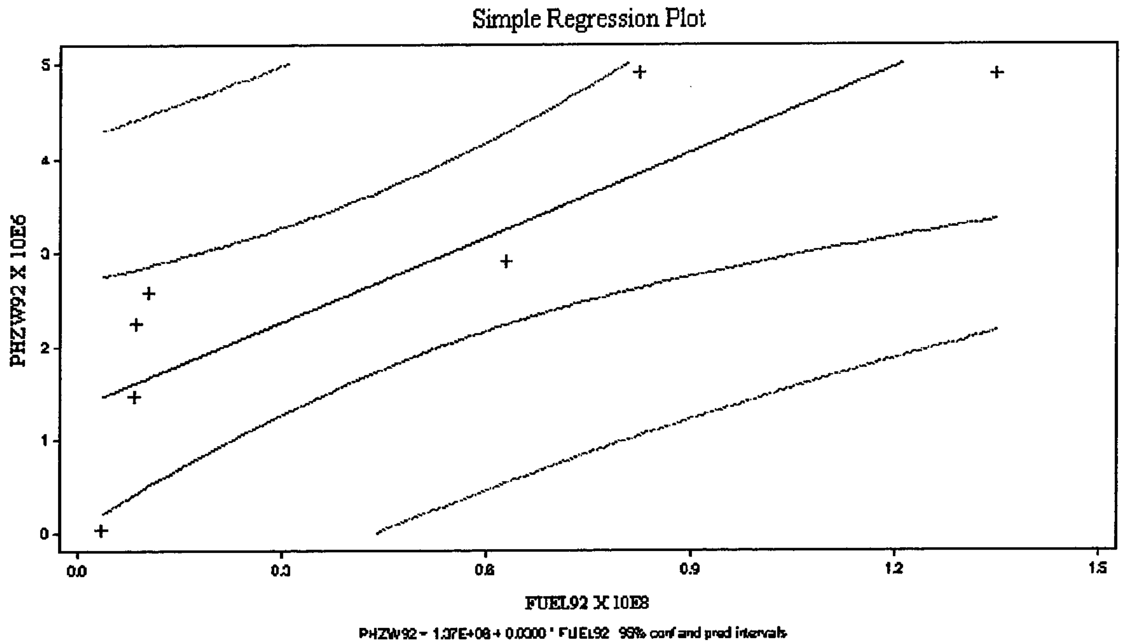
	1992	1993	1994	1995
r	0.8639	0.5412	0.5460	0.6235
p	0.0122	0.2097	0.2048	0.1346

Fuel Capacity. The internal fuel capacity of the fleet of planes in each command was the final aircraft related parameter considered. This variable is one that can readily be found in aircraft literature and, like the previous two variables, is expected to provide excellent information about the size of the planes and their required maintenance. It should be noted that the internal fuel capacity was calculated as the fuel used in that plane only. The excess fuel capacity of KC-135's and KC-10's was not included in these calculations.

The simple linear regression of the fuel weight data for 1992 is displayed in Figure Ten. All but one of the data points fit inside the 95 percent confidence interval and the fit is similar to the take-off weight and empty gross weight variables. As in both of the previous cases, the best fit with the least amount of variance, r^2 equal to 0.7427, came in calendar year 1992. This is an interesting trend that deserves further examination.

Figure 10

Simple regression plot with hazardous waste disposal as the dependent variable and fuel weight as the independent variable



The correlation coefficients range from weak to strong for this variable but the two-tailed p-value still did not give evidence of statistical significance.

Table 7
Correlation coefficients and two-tailed p-values for internal fuel weight

	1992	1993	1994	1995
r	0.8618	0.4651	0.5359	0.6343
p	0.0126	0.2930	0.2150	0.1260

Summary of Activity Analysis

Based upon the simple regression analysis conducted on each of the activity indicator candidates, none of them showed the strong statistical significance that was desired.

The results were not necessarily discouraging; it was just the fact that there was a shortage of data points that precluded of statistical significance at .01 (however, not at say .05). Still, some of the variables clearly seemed to perform better than the others. More specifically, the aircraft related parameters that took into account the relative sizes of the aircraft and the magnitude of their expected maintenance, had the most favorable relationships. Of these, maximum take-off weight had a slightly better indication of association with hazardous waste than the others. This was shown through the correlation coefficient and two-tailed p-value that put it very close to being statistically significant at 95 percent confidence for the 1992 data.

Furthermore it is the author's hypothesis that, with more complete data, a statistically significant association could be demonstrated between the maximum take-off weight and hazardous waste generated. It is therefore reasonable to suggest that an activity index of some sort could be assembled to indicate the amount of hazardous waste generated from such activities. It is proposed that the quantity of hazardous waste generated on an Air Force installation can be explained as a function of such an activity (aircraft maintenance) and pollution prevention efforts (including the HazMat pharmacy). Evidence supports the assumption that the major factor in such an equation would be the activity variable, with the pollution prevention factors comprising a much smaller portion. A notional application of this function was constructed with the information at hand. While recognizing that the degree of uncertainty associated with each of the activity indices developed thus far is far greater than desired, this application is intended to serve as a guide for a more precise model when more comprehensive data is available. Assuming that the amount of hazardous waste generated can be theoretically explained by take-off weight and the pollution prevention efforts, a comparison of non-pharmacy command reductions and pharmacy command reductions was performed. The maximum take-off weight variable was applied as an activity indicator among the flying commands. Figure Eleven shows that the notional difference that could be attributed to the HazMat Pharmacy is approximately 1.45 percent (+/- 9.3). The commands that were included in this analysis were the flying commands. The overseas MAJCOMs (USAFE and PACAF) were also included in this calculation. It should be noted that the pollution prevention efforts in the overseas commands are probably not as enthusiastic as those in the U.S. This is attributable to the fact that Executive Order 12856 does not apply to federal facilities outside the U.S., and is supported by the lagging reductions in hazardous waste disposal overseas. It is also critical to note that AFMC was not included in this initial index because of its non-flying mission. So, while the inclusion of the overseas commands probably hurt the non-pharmacy performance, the exclusion of AFMC also probably hurt the pharmacy commands' performance.

The practical significance of such comparisons is the main issue of concern here. This cannot be realistically done at this time, but any improvement in waste reductions is a positive impact and this is expected to be the case. The confirmation lies in the completion of further research.

Figure 11

The notional activity index analysis of with the adjusted change in quantity difference between pharmacy flying commands and non-pharmacy flying commands

	Pharmacy MAJCOMs		Non-pharmacy MAJOMs	
	ACC, AMC		AETC, ANG, AFSOC, PACAF, USAFE	
	Actual	Adjusted	Actual	Adjusted
lbs	5.98E+06	8.34E+06	6.97E+06	9.52E+06
Reduction (from P2/Pharmacy)		28.27%	26.82%	
Difference (pharmacy) =			1.45%	

The difference attributable to the pharmacy was 1.45 percent, but this value does not exceed the uncertainty of the analysis which was approximately 9 percent. Thus, the uncertainty involved in this analysis precludes any conclusive evidence of pharmacy effectiveness.

V. Conclusions and Recommendations

Summary

The analysis of different aircraft related activity variables provided a basis to construct an index based on more comprehensive data. The different variables had varying degrees of association with the quantity of generated hazardous waste, as expected. However, maximum take-off weight had the strongest association and is the best candidate for use in an index to evaluate the impact of the hazardous materials pharmacy among the flying MAJCOMs.

Nevertheless, more research is required to see if perhaps there are other better activity indicators could be used. Maybe flying hours on a quarterly or monthly basis, if they could be attained, would give better, more accurate trend indications of activity. More frequent measurements of both hazardous waste disposal and activity variables are also needed to increase confidence and reduce uncertainties. Disposal rates on a quarterly or even monthly basis would be adequate and correspond well with an aircraft related variable over the same intervals.

Actual data on the hazardous materials that are purchased by supply or the pharmacy or the whole base (ideally) would give the best indicators of the pharmacy's impact. These numbers would best reflect the reductions in hazardous materials purchases that should be occurring as a result of the pharmacy. Hazardous waste disposal is really only half of the equation. Purchases would give the overall picture and allow for a simple box model to be assembled that shows the cradle-to-grave management of hazardous materials on an Air Force installation. This data should be tracked by supply, especially since they are the official caretakers of the pharmacy. The current tracking system for hazardous materials issued through supply channels does not differentiate many types of hazardous materials and the units they are issued in. Supply should specifically identify and monitor all materials purchased that go through or will go through the HazMat pharmacy, particularly at bases and commands where the pharmacy is yet to be implemented. This would be a valuable tool for expediting the pharmacy transition as well as provide better historical data for comparison and evaluation when the pharmacy is 100 percent installed.

Recommendation for Further Research.

This research effort regretfully did not fully accomplish the objectives that were initially set forth at the beginning of the process. Still, a framework for the assessment of the Hazardous Materials Pharmacy impact was set forth. The immovable obstruction was always the compilation of applicable and consistent data. The pharmacy simply is such a new concept that attempts to gather consistent data across different MAJCOMs proved to be nearly impossible. Each MAJCOM has implemented the pharmacies at its own pace, with different approaches and certainly with varied levels of commander influence imposed on their creation. The gathering of more comprehensive data is paramount for further research efforts.

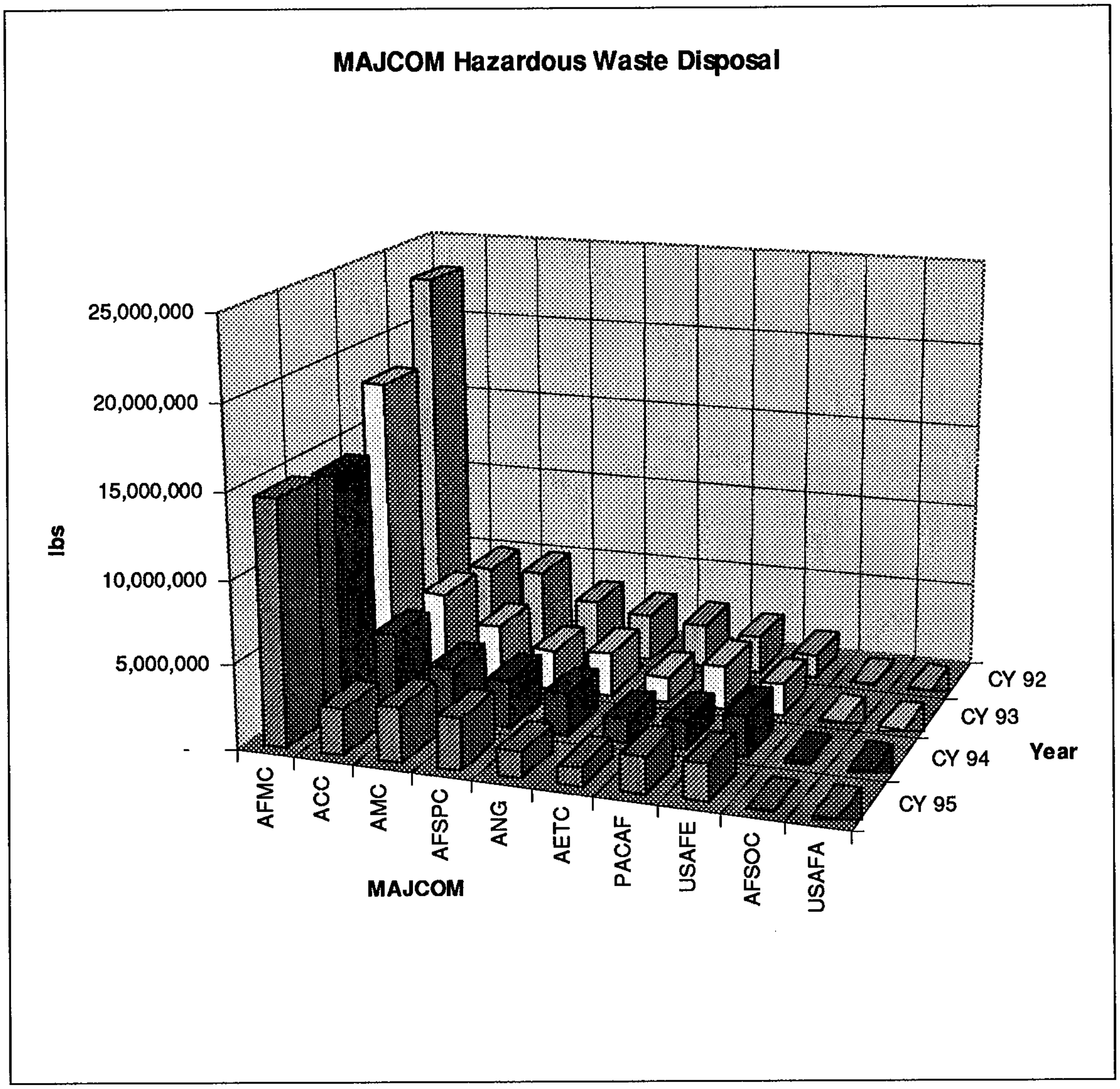
A more narrow focus may be more appropriate for determining the impact of the pharmacy on a base level, for instance, rather than the MAJCOM level. Data is usually easier to obtain at the base level. Some bases have very well kept records of hazardous materials and wastes over the past several years and would be suitable for analysis. However, a MAJCOM level approach could also be conducted successfully. A slightly more elaborate multiple regression analysis or analysis of covariance (ANCOVA) method would probably be best suited to decipher the increased variance that is found in a MAJCOM comparison. Either way, there is a need for valuable feedback that will be useful in the continued development of the Air Force HazMat pharmacy.

Appendix A

Raw Hazardous Waste Disposal Data for MAJCOMs from 1992-1995 in pounds

	CY 95	CY 94	CY 93	CY 92	% reduction
AFMC	14,568,000	14,108,000	17,970,000	23,042,000	36.8%
ACC	2,721,182	4,842,236	5,271,377	4,891,642	44.4%
AMC	3,261,040	3,200,000	3,600,000	4,890,800	33.3%
AFSPC	3,013,900	2,861,317	2,461,920	3,355,335	10.2%
ANG	1,524,325	2,461,043	2,690,000	2,900,000	47.4%
AETC	1,073,768	1,432,000	1,555,000	2,583,000	58.4%
PACAF	2,130,000	1,712,000	2,662,000	2,229,000	4.4%
USAFE	2,226,200	2,468,000	1,926,000	1,446,000	-54.0%
AFSOC	15,400	154,800	38,400	22,000	30.0%
USAFA	29,160	19,596	32,090	34,784	16.2%

Histogram of hazardous waste disposal for MAJCOMs from 1992-1995



Appendix B

1995 EQUIVALENTS FOR DIFFERENT AIRCRAFT CLASSES

BOMBERS	# in inventory	Engines	Empty Gross wt (lbs)	Fuel Cap	Max TO wt (lbs)
B-1	84	4	115,000	155,000	400,000
B-2	14	4	105,000	190,000	400,000
B-52	85	8	172,800	150,000	488,000
	183				

AVG NUMBER OF ENGINES **5.858**

AVERAGE EMPTY GROSS WT **141,082**

AVERAGE FUEL CAPACITY(lbs) **155,355**

AVERAGE MAXIMUM TO WT.(lbs) **440,874**

CARGO/TRANSPT	# in inventory	Engines	Empty Gross wt (lbs)	Fuel Cap	Max TO wt (lbs)
C-5	81	4	370,300	332,500	800,000
C-12	44	2	8,100	3,645	12,500
C-17	23	4	270,000	139,000	580,000
C-21	78	2	10,119	3,300	18,300
C-130	205	4	76,000	44,300	155,000
C-141	185	4	148,120	104,000	333,000
	616				

AVG NUMBER OF ENGINES **3.604**

AVERAGE EMPTY GROSS WT **130,409**

AVERAGE FUEL CAPACITY (lbs) **95,566**

AVERAGE MAXIMUM TO WT.(lbs) **281,652**

ELECTRONIC WARFARE	#				
F-4G	40	2	31,300	10,000	61,800
EF-111	40	2	47,500	15,000	100,000
	80				

AVG NUMBER OF ENGINES **2.00**

AVERAGE EMPTY GROSS WT **39,400**

AVERAGE FUEL CAPACITY(lbs) **12,500**

AVERAGE MAXIMUM TO WT.(lbs) **80,900**

FIGHTER/ATTACK	#	Engines	Empty Gross wt	Fuel Cap (lbs)	Max TO wt (lbs)
A-10	231	2	21,500	10,700	50,000
F-15	628	2	32,000	13,100	68,000
F-16	780	1	18,500	6,200	40,000
F-111	102	2	47,500	15,000	100,000
F-117	57	2	29,500	18,000	52,500
	1,798				

AVG NUMBER OF ENGINES **1.566**

AVERAGE EMPTY GROSS WT **25,595**

AVERAGE FUEL CAPACITY(lbs) **10,061**

AVERAGE MAXIMUM TO WT.(lbs) **54,865**

HELICOPTER	#	Engines	Empty Gross wt	Fuel Cap (lbs)	Max TO wt (lbs)
HH/UH-1	80	1	6,600	2,086	10,000
HH-60	43	2	11,500	2,640	22,000
TH-53	7	3	34,500	12,000	73,500
	130				

AVG NUMBER OF ENGINES **1.438**

AVERAGE EMPTY GROSS WT **9,723**

AVERAGE FUEL CAPACITY(lbs) **2,803**

AVERAGE MAXIMUM TO WT(lbs) **17,388**

RECON/C3I	#	Engines	Empty Gross wt	Fuel Cap (lbs)	Max TO wt (lbs)
E-3	33	4	160,000	155,448	332,500
W/RC-135	42	4	99,000	140,000	322,500
U-2	32	1	17,000	10,000	40,000
EC-130	22	4	76,000	44,300	155,000
	129				

AVG NUMBER OF ENGINES **3.256**

AVERAGE EMPTY GROSS WT **90,341**

AVERAGE FUEL CAPACITY(lbs) **95,383**

AVERAGE MAXIMUM TO WT(lbs) **226,415**

SPEC OPS	#	Engines	Empty Gross wt	Fuel Cap (lbs)	Max TO wt (lbs)
C130	87	4	76,000	44,300	155,000
CH-53	40	3	34,500	12,000	73,500
H-60	13	2	11,500	2,640	22,000
	140				

AVG NUMBER OF ENGINES **3.529**

AVERAGE EMPTY GROSS WT **58,154**

AVERAGE FUEL CAPACITY(lbs) **31,203**

AVERAGE MAXIMUM TO WT(lbs) **119,364**

TANKER					
HC-130	3	4	76,000	44,300	155,000
KC-10	59	3	240,000	180,600	590,000
KC-135	263	4	99,000	140,000	322,500
	325				

AVG NUMBER OF ENGINES **3.818**

AVERAGE EMPTY GROSS WT **124,385**

AVERAGE FUEL CAPACITY(lbs) **146,487**

AVERAGE MAXIMUM TO WT(lbs) **369,515**

TRAINER					
T-1	123	2	10,100	4,912	16,100
T-3	95	1	1,780	252	2,525
T-37	461	2	4,000	1,800	6,500
T-38	471	2	7,600	3,600	12,050
	1,150				

AVG NUMBER OF ENGINES **1.917**

AVERAGE EMPTY GROSS WT **5,943**

AVERAGE FUEL CAPACITY(lbs) **2,742**

AVERAGE MAXIMUM TO WT(lbs) **9,472**

MOBILITY AIRCRAFT

C-5	81	4	370,300	332,500	800,000
C-17	23	4	270,000	139,000	580,000
C-141	185	4	148,120	104,000	333,000
KC-10	59	3	240,000	180,600	590,000
KC-135	263	4	99,000	140,000	322,500
	611				

AVG NUMBER OF ENGINES **3.9034**

AVERAGE EMPTY GROSS WT **169,891**

AVERAGE FUEL CAPACITY(lbs) **158,502**

AVERAGE MAXIMUM TO WT(lbs) **424,505**

Appendix C

1995 ACC AIRCRAFT EQUIVALENCY CACULATIONS								
NUMBER OF BOMBERS (B-1, B-2, B-52) IN ACC =					123			
			Engines	5.858		Be =	720.5	
			Gross wt	141082		Bg =	1.74E+07	
			Fuel	155355		Bf =	1.91E+07	
			Max TO wt	440,874		Bt =	5.42E+07	
NUMBER OF FIGHTER/ATTACK A/C =				549				
			Engines	1.566		Fe =	859.7	
			Gross wt	25,595		Fg =	1.41E+07	
			Fuel	10,061		Ff =	5.52E+06	
			Max TO wt	54,865		Ft =	3.01E+07	
NUMBER OF EC/EW A/C =			36					
			Engines	2.00		Ee =	72.0	
			Gross wt	39400		Eg =	1.42E+06	
			Fuel	12500		Ef =	4.50E+05	
			Max TO wt	80900		Et =	2.91E+06	
NUMBER OF REFUELERS (KC-135) =				6				
			Engines	4.00		Re =	24.0	
			Gross wt	99000		Rg =	594,000	
			Fuel	140000		Rf =	840,000	
			Max TO wt	322500		Rt =	1.94E+06	
NUMBER OF CARGO(C-130, C-27) =				131				
			Engines	3.604		Ce =	472.1	
			Gross wt	130,409		Cg =	1.71E+07	
			Fuel	95,566		Cf =	1.25E+07	
			Max TO wt	281,652		Ct =	3.69E+07	
NUMBER OF "OTHER" A/C (RECON) =				175				
			Engines	3.256		Oe =	569.8	
			Gross wt	90,341		Og =	1.58E+07	
			Fuel	95,383		Of =	1.67E+07	
			Max TO wt	226,415		Ot =	3.96E+07	
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total		
2718		6.63E+07		5.51E+07		1.66E+08		
TOTAL AIRCRAFT =		1,020						

1994 ACC AIRCRAFT EQUIVALENCY CACULATIONS								
NUMBER OF BOMBERS (B-1, B-2, B-52) IN ACC =					**121**			
			Engines	**5.858**		Be =	**708.8**	
			Gross wt	**141082**		Bg =	**1.71E+07**	
			Fuel	**155355**		Bf =	**1.88E+07**	
			Max TO wt	**440,874**		Bt =	**5.33E+07**	
NUMBER OF FIGHTER/ATTACK A/C =				**555**				
			Engines	**1.566**		Fe =	**869.1**	
			Gross wt	**25,595**		Fg =	**1.42E+07**	
			Fuel	**10,061**		Ff =	**5.58E+06**	
			Max TO wt	**54,865**		Ft =	**3.05E+07**	
NUMBER OF EC/EW A/C =			**48**					
			Engines	**2.00**		Ee =	**96.0**	
			Gross wt	**39400**		Eg =	**1.89E+06**	
			Fuel	**12500**		Ef =	**6.00E+05**	
			Max TO wt	**80900**		Et =	**3.88E+06**	
NUMBER OF REFUELERS (KC-10,135) =				**12**				
			Engines	**4.00**		Re =	**48.0**	
			Gross wt	**150000**		Rg =	**1.80E+06**	
			Fuel	**155000**		Rf =	**1.86E+06**	
			Max TO wt	**385000**		Rt =	**4.62E+06**	
NUMBER OF CARGO(C-130, C-27) =				**135**				
			Engines	**3.604**		Ce =	**486.5**	
			Gross wt	**130,409**		Cg =	**1.76E+07**	
			Fuel	**95,566**		Cf =	**1.29E+07**	
			Max TO wt	**281,652**		Ct =	**3.80E+07**	
NUMBER OF "OTHER" A/C (RECON) =				**175**				
			Engines	**3.256**		Oe =	**569.8**	
			Gross wt	**90,341**		Og =	**1.58E+07**	
			Fuel	**95,383**		Of =	**1.67E+07**	
			Max TO wt	**226,415**		Ot =	**3.96E+07**	
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total		
2778		**6.84E+07**		**5.64E+07**		**1.70E+08**		
TOTAL AIRCRAFT =		**1,046**						

1993 ACC AIRCRAFT EQUIVALENCY CACULATIONS								
NUMBER OF BOMBERS (B-1, B-2, B-52) IN ACC =					**166**			
			Engines	**5.858**		Be =	**972.4**	
			Gross wt	**141082**		Bg =	**2.34E+07**	
			Fuel	**155355**		Bf =	**2.58E+07**	
			Max TO wt	**440,874**		Bt =	**7.32E+07**	
NUMBER OF FIGHTER/ATTACK A/C =				**606**				
			Engines	**1.566**		Fe =	**949.0**	
			Gross wt	**25,595**		Fg =	**1.55E+07**	
			Fuel	**10,061**		Ff =	**6.10E+06**	
			Max TO wt	**54,865**		Ft =	**3.32E+07**	
NUMBER OF EC/EW A/C =			**45**					
			Engines	**2.00**		Ee =	**90.0**	
			Gross wt	**39400**		Eg =	**1.77E+06**	
			Fuel	**12500**		Ef =	**5.63E+05**	
			Max TO wt	**80900**		Et =	**3.64E+06**	
NUMBER OF REFUELERS (KC-10,135) =				**25**				
			Engines	**4.00**		Re =	**100.0**	
			Gross wt	**150000**		Rg =	**3.75E+06**	
			Fuel	**155000**		Rf =	**3.88E+06**	
			Max TO wt	**385000**		Rt =	**9.63E+06**	
NUMBER OF CARGO(C-130, C-27) =				**-**				
			Engines	**3.604**		Ce =	**0.0**	
			Gross wt	**130,409**		Cg =	**0.00E+00**	
			Fuel	**95,566**		Cf =	**0.00E+00**	
			Max TO wt	**281,652**		Ct =	**0.00E+00**	
NUMBER OF "OTHER" A/C (RECON) =				**381**				
			Engines	**3.256**		Oe =	**1240.536**	
			Gross wt	**90,341**		Og =	**3.44E+07**	
			Fuel	**95,383**		Of =	**3.63E+07**	
			Max TO wt	**226,415**		Ot =	**8.63E+07**	
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total		
3352		**7.89E+07**		**7.27E+07**		**2.06E+08**		
TOTAL AIRCRAFT =		**1,223**						

1992 ACC AIRCRAFT EQUIVALENCY CACULATIONS								
NUMBER OF BOMBERS (B-1, B-52) IN ACC =					201			
			Engines	5.858		Be =	1177.5	
			Gross wt	141082		Bg =	2.84E+07	
			Fuel	155355		Bf =	3.12E+07	
			Max TO wt	440,874		Bt =	8.86E+07	
NUMBER OF FIGHTER/ATTACK A/C =				1071				
			Engines	1.566		Fe =	1,677.2	
			Gross wt	25,595		Fg =	2.74E+07	
			Fuel	10,061		Ff =	1.08E+07	
			Max TO wt	54,865		Ft =	5.88E+07	
NUMBER OF EC/EW A/C =			39					
			Engines	2.00		Ee =	78.0	
			Gross wt	39400		Eg =	1.54E+06	
			Fuel	12500		Ef =	4.88E+05	
			Max TO wt	80900		Et =	3.16E+06	
NUMBER OF REFUELERS (KC-10,135) =				73				
			Engines	4.00		Re =	292.0	
			Gross wt	150000		Rg =	1.10E+07	
			Fuel	155000		Rf =	1.13E+07	
			Max TO wt	385000		Rt =	2.81E+07	
NUMBER OF CARGO(C-130, C-27) =				-				
			Engines	3.604		Ce =	0.0	
			Gross wt	130,409		Cg =	0.00E+00	
			Fuel	95,566		Cf =	0.00E+00	
			Max TO wt	281,652		Ct =	0.00E+00	
NUMBER OF "OTHER" A/C (RECON) =				304				
			Engines	3.256		Oe =	989.824	
			Gross wt	90,341		Og =	2.75E+07	
			Fuel	95,383		Of =	2.90E+07	
			Max TO wt	226,415		Ot =	6.88E+07	
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total		
4214		9.57E+07		8.28E+07		2.47E+08		
TOTAL AIRCRAFT =		1,688						

1995 AETC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF TRAINERS (T-1,3,37,38) =				**1,159**				
			Engines	**1.917**		Te =	**2,221.8**	
			Gross wt	**5,943**		Tg =	**6.89E+06**	
			Fuel	**2,742**		Tf =	**3.18E+06**	
			Max TO wt	**9,472**		Tt =	**1.10E+07**	
NUMBER OF FIGHTERS (F-15,16) =				**279**				
			Engines	**1.566**		Fe =	**436.9**	
			Gross wt	**25,595**		Fg =	**7.14E+06**	
			Fuel	**10,061**		Ff =	**2.81E+06**	
			Max TO wt	**54,865**		Ft =	**1.53E+07**	
NUMBER OF TRANSPORTS & TANKERS				**84**				
			Engines	**3.604**		Ce =	**302.7**	
			Gross wt	**130,409**		Cg =	**1.10E+07**	
			Fuel	**95,566**		Cf =	**8.03E+06**	
			Max TO wt	**281,652**		Ct =	**2.37E+07**	
NUMBER OF HELICOPTERS =				**27**				
			Engines	**1.438**		He =	**38.8**	
			Gross wt	**9,723**		Hg =	**262,521**	
			Fuel	**2,803**		Hf =	**75,681**	
			Max TO wt	**17,388**		Ht =	**469,476**	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
3000		**2.52E+07**		**1.41E+07**		**5.04E+07**		
TOTAL AIRCRAFT =		**1,549**						

1994 AETC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF TRAINERS (T-1,3,37,38) =				**1,120**				
			Engines	**1.917**		Te =	**2,147.0**	
			Gross wt	**5,943**		Tg =	**6.66E+06**	
			Fuel	**2,742**		Tf =	**3.07E+06**	
			Max TO wt	**9,472**		Tt =	**1.06E+07**	
NUMBER OF FIGHTERS (F-15,16) =				**278**				
			Engines	**1.566**		Fe =	**435.3**	
			Gross wt	**25,595**		Fg =	**7.12E+06**	
			Fuel	**10,061**		Ff =	**2.80E+06**	
			Max TO wt	**54,865**		Ft =	**1.53E+07**	
NUMBER OF TRANSPORTS & TANKERS				**80**				
			Engines	**3.604**		Ce =	**288.3**	
			Gross wt	**130,409**		Cg =	**1.04E+07**	
			Fuel	**95,566**		Cf =	**7.65E+06**	
			Max TO wt	**281,652**		Ct =	**2.25E+07**	
NUMBER OF HELICOPTERS				**26**				
			Engines	**1.438**		He =	**37.4**	
			Gross wt	**9,723**		Hg =	**252,798**	
			Fuel	**2,803**		Hf =	**72,878**	
			Max TO wt	**17,388**		Ht =	**452,088**	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
2908		**2.45E+07**		**1.36E+07**		**4.88E+07**		
TOTAL AIRCRAFT =		**1,504**						

1993 AETC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF TRAINERS (T-1,3,37,38) =				**1,109**				
			Engines	**1.917**		Te =	**2,126.0**	
			Gross wt	**5,943**		Tg =	**6.59E+06**	
			Fuel	**2,742**		Tf =	**3.04E+06**	
			Max TO wt	**9,472**		Tt =	**1.05E+07**	
NUMBER OF FIGHTERS (F-15,16) =				**239**				
			Engines	**1.566**		Fe =	**374.3**	
			Gross wt	**25,595**		Fg =	**6.12E+06**	
			Fuel	**10,061**		Ff =	**2.40E+06**	
			Max TO wt	**54,865**		Ft =	**1.31E+07**	
NUMBER OF TRANSPORTS & TANKERS				**68**				
			Engines	**3.604**		Ce =	**245.1**	
			Gross wt	**130,409**		Cg =	**8.87E+06**	
			Fuel	**95,566**		Cf =	**6.50E+06**	
			Max TO wt	**281,652**		Ct =	**1.92E+07**	
NUMBER OF HELICOPTERS				**28**				
			Engines	**1.438**		He =	**40.3**	
			Gross wt	**9,723**		Hg =	**272,244**	
			Fuel	**2,803**		Hf =	**78,484**	
			Max TO wt	**17,388**		Ht =	**486,864**	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
2786		**2.18E+07**		**1.20E+07**		**4.33E+07**		
TOTAL AIRCRAFT =		**1,444**						

1992 AETC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF TRAINERS (T-1,3,37,38) =				1,210				
			Engines	1.917		Te =	2,319.6	
			Gross wt	5,943		Tg =	7.19E+06	
			Fuel	2,742		Tf =	3.32E+06	
			Max TO wt	9,472		Tt =	1.15E+07	
NUMBER OF FIGHTERS (F-15,16) =				213				
			Engines	1.566		Fe =	333.6	
			Gross wt	25,595		Fg =	5.45E+06	
			Fuel	10,061		Ff =	2.14E+06	
			Max TO wt	54,865		Ft =	1.17E+07	
NUMBER OF TRANSPORTS & TANKERS				53				
			Engines	3.604		Ce =	191.0	
			Gross wt	130,409		Cg =	6.91E+06	
			Fuel	95,566		Cf =	5.06E+06	
			Max TO wt	281,652		Ct =	1.49E+07	
NUMBER OF HELICOPTERS				21				
			Engines	1.438		He =	30.2	
			Gross wt	9,723		Hg =	204,183	
			Fuel	2,803		Hf =	58,863	
			Max TO wt	17,388		Ht =	365,148	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
2874		1.98E+07		1.06E+07		3.84E+07		
TOTAL AIRCRAFT =		1,497						

1995 AFSOC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF C-130S(MC,EC,AC)			=	**83**				
			Engines	**4.00**		Ce =	**332.0**	
			Gross wt	**76,000**		Cg =	**6.31E+06**	
			Fuel	**44,300**		Cf =	**3.68E+06**	
			Max TO wt	**155,000**		Ct =	**1.29E+07**	
NUMBER OF MH-53 HELICOPTERS =				**36**				
			Engines	**3.00**		He =	**108.0**	
			Gross wt	**34,500**		Hg =	**1.24E+06**	
			Fuel	**12,000**		Hf =	**432,000**	
			Max TO wt	**73,500**		Ht =	**2.65E+06**	
NUMBER OF MH-60 HELICOPTERS =				**10**				
			Engines	**2**		hE =	**20.0**	
			Gross wt	**11,500**		hG =	**115,000**	
			Fuel	**2,640**		hF =	**26,400**	
			Max TO wt	**22,000**		hT =	**220,000**	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
460		**7.67E+06**		**4.14E+06**		**1.57E+07**		
TOTAL AIRCRAFT =		**129**						

1994 AFSOC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF C-130S(MC,EC,AC)			=	**95**				
			Engines	**4.00**		Ce =	**380.0**	
			Gross wt	**76,000**		Cg =	**7.22E+06**	
			Fuel	**44,300**		Cf =	**4.21E+06**	
			Max TO wt	**155,000**		Ct =	**1.47E+07**	
NUMBER OF MH-53 HELICOPTERS =				**39**				
			Engines	**3.00**		He =	**117.0**	
			Gross wt	**34,500**		Hg =	**1.35E+06**	
			Fuel	**12,000**		Hf =	**468,000**	
			Max TO wt	**73,500**		Ht =	**2.87E+06**	
NUMBER OF MH-60 HELICOPTERS =				**10**				
			Engines	**2**		hE =	**20.0**	
			Gross wt	**11,500**		hG =	**115,000**	
			Fuel	**2,640**		hF =	**26,400**	
			Max TO wt	**22,000**		hT =	**220,000**	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
517		**8.68E+06**		**4.70E+06**		**1.78E+07**		
TOTAL AIRCRAFT =		**144**						

1993 AFSOC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF C-130S(MC,EC,AC) =				89				
			Engines	4.00		Ce =	356.0	
			Gross wt	76,000		Cg =	6.76E+06	
			Fuel	44,300		Cf =	3.94E+06	
			Max TO wt	155,000		Ct =	1.38E+07	
NUMBER OF MH-53 HELICOPTERS =				39				
			Engines	3.00		He =	117.0	
			Gross wt	34,500		Hg =	1.35E+06	
			Fuel	12,000		Hf =	468,000	
			Max TO wt	73,500		Ht =	2.87E+06	
NUMBER OF MH-60 HELICOPTERS =				10				
			Engines	2		hE =	20.0	
			Gross wt	11,500		hG =	115,000	
			Fuel	2,640		hF =	26,400	
			Max TO wt	22,000		hT =	220,000	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
493		8.22E+06		4.44E+06		1.69E+07		
TOTAL AIRCRAFT =		138						

1992 AFSOC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF C-130S(MC,EC,AC) =				71				
			Engines	4.00		Ce =	284.0	
			Gross wt	76,000		Cg =	5.40E+06	
			Fuel	44,300		Cf =	3.15E+06	
			Max TO wt	155,000		Ct =	1.10E+07	
NUMBER OF MH-53 HELICOPTERS =				36				
			Engines	3.00		He =	108.0	
			Gross wt	34,500		Hg =	1.24E+06	
			Fuel	12,000		Hf =	432,000	
			Max TO wt	73,500		Ht =	2.65E+06	
NUMBER OF MH-60 HELICOPTERS =				20				
			Engines	2		hE =	40.0	
			Gross wt	11,500		hG =	230,000	
			Fuel	2,640		hF =	52,800	
			Max TO wt	22,000		hT =	440,000	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
432		6.87E+06		3.63E+06		1.41E+07		
TOTAL AIRCRAFT =		127						

1995 AMC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF MOBILITY AIRCRAFT =				824				
			Engines	3.903		Me =	3216.4	
			Gross wt	169,891		Mg =	1.4E+08	
			Fuel	158,502		Mf =	1.31E+08	
			Max TO wt	424,505		Mt =	3.5E+08	
AEROMEDICAL AIRCRAFT (C-9) =				12				
			Engines	2		Ae =	24	
			Gross wt	62,200		Ag =	746,400	
			Fuel	21,000		Af =	252,000	
			Max TO wt	108,000		At =	1.30E+06	
"OTHER" AIRCRAFT (C-20,21,9, UH-1) =				88				
use cargo a/c #'s			Engines	3.604		Oe =	317.2	
			Gross wt	130,409		Og =	1.15E+07	
			Fuel	95,566		Of =	8.41E+06	
			Max TO wt	281,652		Ot =	2.48E+07	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
3534		1.52E+08	lbs	1.39E+08	lbs	3.75E+08	lbs	
TOTAL AIRCRAFT =		924						

1994 AMC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF MOBILITY AIRCRAFT =				909				
			Engines	3.903		Me =	3548.2	
			Gross wt	169,891		Mg =	1.54E+08	
			Fuel	158,502		Mf =	1.44E+08	
			Max TO wt	424,505		Mt =	3.86E+08	
AEROMEDICAL AIRCRAFT (C-9) =				12				
			Engines	2		Ae =	24	
			Gross wt	62,200		Ag =	746,400	
			Fuel	21,000		Af =	252,000	
			Max TO wt	108,000		At =	1.30E+06	
"OTHER" AIRCRAFT (C-20,21,9, UH-1) =				94				
use cargo a/c #'s			Engines	3.604		Oe =	338.8	
			Gross wt	130,409		Og =	1.23E+07	
			Fuel	95,566		Of =	8.98E+06	
			Max TO wt	281,652		Ot =	2.65E+07	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
3887		1.67E+08	lbs	1.53E+08	lbs	4.12E+08	lbs	
TOTAL AIRCRAFT =		1015						

1993 AMC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF MOBILITY AIRCRAFT =				**808**				
			Engines	**3.903**		Me =	**3153.9**	
			Gross wt	**169,891**		Mg =	**1.37E+08**	
			Fuel	**158,502**		Mf =	**1.28E+08**	
			Max TO wt	**424,505**		Mt =	**3.43E+08**	
AEROMEDICAL AIRCRAFT (C-9) =				**12**				
			Engines	**2**		Ae =	**24**	
			Gross wt	**62,200**		Ag =	**746,400**	
			Fuel	**21,000**		Af =	**252,000**	
			Max TO wt	**108,000**		At =	**1.30E+06**	
"OTHER" AIRCRAFT (C-20,21,9, UH-1) =				**94**				
use cargo a/c #'s			Engines	**3.604**		Oe =	**338.8**	
			Gross wt	**130,409**		Og =	**1.23E+07**	
			Fuel	**95,566**		Of =	**8.98E+06**	
			Max TO wt	**281,652**		Ot =	**2.65E+07**	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
3493		**1.50E+08**	lbs	**1.37E+08**	lbs	**3.69E+08**	lbs	
TOTAL AIRCRAFT =		**914**						
1992 AMC AIRCRAFT EQUIVALENCY CALCULATIONS								
NUMBER OF MOBILITY AIRCRAFT =				**784**				
			Engines	**3.903**		Me =	**3060.3**	
			Gross wt	**169,891**		Mg =	**1.33E+08**	
			Fuel	**158,502**		Mf =	**1.24E+08**	
			Max TO wt	**424,505**		Mt =	**3.33E+08**	
AEROMEDICAL AIRCRAFT (C-9) =				**12**				
			Engines	**2**		Ae =	**24**	
			Gross wt	**62,200**		Ag =	**746,400**	
			Fuel	**21,000**		Af =	**252,000**	
			Max TO wt	**108,000**		At =	**1.30E+06**	
"OTHER" AIRCRAFT (C-20,21,9, UH-1) =				**106**				
use cargo a/c #'s			Engines	**3.604**		Oe =	**382.0**	
			Gross wt	**130,409**		Og =	**1.38E+07**	
			Fuel	**95,566**		Of =	**1.01E+07**	
			Max TO wt	**281,652**		Ot =	**2.99E+07**	
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total		
3442		**1.48E+08**	lbs	**1.35E+08**	lbs	**3.63E+08**	lbs	
TOTAL AIRCRAFT =		**902**						

1995 ANG AIRCRAFT EQUIVALENCY CACULATIONS								
NUMBER OF BOMBERS (B-1, B-2, B-52) IN ACC =					**11**			
			Engines	**5.858**		Be =	**64.4**	
			Gross wt	**141082**		Bg =	**1.55E+06**	
			Fuel	**155355**		Bf =	**1.71E+06**	
			Max TO wt	**440,874**		Bt =	**4.85E+06**	
NUMBER OF FIGHTER/ATTACK A/C =				**911**				
			Engines	**1.566**		Fe =	**1,426.6**	
			Gross wt	**25,595**		Fg =	**2.33E+07**	
			Fuel	**10,061**		Ff =	**9.17E+06**	
			Max TO wt	**54,865**		Ft =	**5.00E+07**	
NUMBER OF REFUELERS (KC-135) =				**224**				
			Engines	**4.00**		Re =	**896.0**	
			Gross wt	**99000**		Rg =	**2.22E+07**	
			Fuel	**140000**		Rf =	**3.14E+07**	
			Max TO wt	**322500**		Rt =	**7.22E+07**	
NUMBER OF CARGO(C-130, C-27) =				**307**				
			Engines	**3.604**		Ce =	**1106.4**	
			Gross wt	**130,409**		Cg =	**4.00E+07**	
			Fuel	**95,566**		Cf =	**2.93E+07**	
			Max TO wt	**281,652**		Ct =	**8.65E+07**	
NUMBER OF HELICOPTERS (HH-60) =				**18**				
			Engines	**2.000**		Oe =	**36**	
			Gross wt	**11,500**		Og =	**2.07E+05**	
			Fuel	**2,640**		Of =	**4.75E+04**	
			Max TO wt	**22,000**		Ot =	**3.96E+05**	
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total		
3529		**8.73E+07**		**7.16E+07**		**2.14E+08**		
TOTAL AIRCRAFT =		**1,471**						

1994 ANG AIRCRAFT EQUIVALENCY CACULATIONS							
NUMBER OF BOMBERS (B-1, B-2, B-52) IN ACC =					11		
			Engines	5.858		Be =	64.4
			Gross wt	141082		Bg =	1.55E+06
			Fuel	155355		Bf =	1.71E+06
			Max TO wt	440,874		Bt =	4.85E+06
NUMBER OF FIGHTER/ATTACK A/C =				1046			
			Engines	1.566		Fe =	1,638.0
			Gross wt	25,595		Fg =	2.68E+07
			Fuel	10,061		Ff =	1.05E+07
			Max TO wt	54,865		Ft =	5.74E+07
NUMBER OF REFUELERS (KC-135) =				225			
			Engines	4.00		Re =	900.0
			Gross wt	99000		Rg =	2.23E+07
			Fuel	140000		Rf =	3.15E+07
			Max TO wt	322500		Rt =	7.26E+07
NUMBER OF CARGO(C-130, C-27) =				293			
			Engines	3.604		Ce =	1056.0
			Gross wt	130,409		Cg =	3.82E+07
			Fuel	95,566		Cf =	2.80E+07
			Max TO wt	281,652		Ct =	8.25E+07
NUMBER OF HELICOPTERS (HH-60) =				21			
			Engines	2.000		Oe =	42
			Gross wt	11,500		Og =	2.42E+05
			Fuel	2,640		Of =	5.54E+04
			Max TO wt	22,000		Ot =	4.62E+05
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total	
3700		8.91E+07		7.18E+07		2.18E+08	
TOTAL AIRCRAFT =		1,596					

1993 ANG AIRCRAFT EQUIVALENCY CACULATIONS							
NUMBER OF BOMBERS (B-1, B-2, B-52) IN ACC =					**0**		
			Engines	**5.858**		Be =	**0.0**
			Gross wt	**141082**		Bg =	**0.00E+00**
			Fuel	**155355**		Bf =	**0.00E+00**
			Max TO wt	**440,874**		Bt =	**0.00E+00**
NUMBER OF FIGHTER/ATTACK A/C =				**1165**			
			Engines	**1.566**		Fe =	**1,824.4**
			Gross wt	**25,595**		Fg =	**2.98E+07**
			Fuel	**10,061**		Ff =	**1.17E+07**
			Max TO wt	**54,865**		Ft =	**6.39E+07**
NUMBER OF REFUELERS (KC-135) =				**184**			
			Engines	**4.00**		Re =	**736.0**
			Gross wt	**99000**		Rg =	**1.82E+07**
			Fuel	**140000**		Rf =	**2.58E+07**
			Max TO wt	**322500**		Rt =	**5.93E+07**
NUMBER OF CARGO(C-130, C-27) =				**287**			
			Engines	**3.604**		Ce =	**1034.3**
			Gross wt	**130,409**		Cg =	**3.74E+07**
			Fuel	**95,566**		Cf =	**2.74E+07**
			Max TO wt	**281,652**		Ct =	**8.08E+07**
NUMBER OF HELICOPTERS (HH-60) =				**16**			
			Engines	**2.000**		Oe =	**32**
			Gross wt	**11,500**		Og =	**1.84E+05**
			Fuel	**2,640**		Of =	**4.22E+04**
			Max TO wt	**22,000**		Ot =	**3.52E+05**
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total	
3627		**8.56E+07**		**6.50E+07**		**2.04E+08**	
TOTAL AIRCRAFT =		**1,652**					

1992 ANG AIRCRAFT EQUIVALENCY CACULATIONS							
NUMBER OF BOMBERS (B-1, B-2, B-52) IN ACC =					**0**		
			Engines	**5.858**		Be =	**0.0**
			Gross wt	**141082**		Bg =	**0.00E+00**
			Fuel	**155355**		Bf =	**0.00E+00**
			Max TO wt	**440,874**		Bt =	**0.00E+00**
NUMBER OF FIGHTER/ATTACK A/C =				**1280**			
			Engines	**1.566**		Fe =	**2,004.5**
			Gross wt	**25,595**		Fg =	**3.28E+07**
			Fuel	**10,061**		Ff =	**1.29E+07**
			Max TO wt	**54,865**		Ft =	**7.02E+07**
NUMBER OF REFUELERS (KC-135) =				**160**			
			Engines	**4.00**		Re =	**640.0**
			Gross wt	**99000**		Rg =	**1.58E+07**
			Fuel	**140000**		Rf =	**2.24E+07**
			Max TO wt	**322500**		Rt =	**5.16E+07**
NUMBER OF CARGO(C-130, C-27) =				**291**			
			Engines	**3.604**		Ce =	**1048.8**
			Gross wt	**130,409**		Cg =	**3.79E+07**
			Fuel	**95,566**		Cf =	**2.78E+07**
			Max TO wt	**281,652**		Ct =	**8.20E+07**
NUMBER OF HELICOPTERS (HH-60) =				**15**			
			Engines	**2.000**		Oe =	**30**
			Gross wt	**11,500**		Og =	**1.73E+05**
			Fuel	**2,640**		Of =	**3.96E+04**
			Max TO wt	**22,000**		Ot =	**3.30E+05**
Engine Total		Gross Wt Total		Fuel Wt. Total		Max TO Wt Total	
3723		**8.67E+07**		**6.31E+07**		**2.04E+08**	
TOTAL AIRCRAFT =		**1,746**					

1995 USAFE AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				174			
			Engines	1.566		Fe =	272.5
			Gross wt	25,595		Fg =	4.45E+06
			Fuel	10,061		Ff =	1.75E+06
			Max TO wt	54,865		Ft =	9.55E+06
NUMBER OF "OTHER" A/C (TANKERS,				47			
TRANSPORT/RECON			Engines	3.604		Oe =	169.4
			Gross wt	130,409		Og =	6.13E+06
			Fuel	95,566		Of =	4.49E+06
			Max TO wt	281,652		Ot =	1.32E+07
TOTAL AIRCRAFT =		221					
Engine Total		Gross Wt Total		Fuel Total		Max TO Wt Total	
442		1.06E+07		6.24E+06		2.28E+07	

1994 USAFE AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				174			
			Engines	1.566		Fe =	272.5
			Gross wt	25,595		Fg =	4.45E+06
			Fuel	10,061		Ff =	1.75E+06
			Max TO wt	54,865		Ft =	9.55E+06
NUMBER OF "OTHER" A/C (TANKERS,				47			
TRANSPORT/RECON			Engines	3.604		Oe =	169.4
			Gross wt	130,409		Og =	6.13E+06
			Fuel	95,566		Of =	4.49E+06
			Max TO wt	281,652		Ot =	1.32E+07
TOTAL AIRCRAFT =		221					
Engine Total		Gross Wt Total		Fuel Total		Max TO Wt Total	
442		1.06E+07		6.24E+06		2.28E+07	

1993 USAFE AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				**174**			
			Engines	**1.566**		Fe =	**272.5**
			Gross wt	**25,595**		Fg =	**4.45E+06**
			Fuel	**10,061**		Ff =	**1.75E+06**
			Max TO wt	**54,865**		Ft =	**9.55E+06**
NUMBER OF "OTHER" A/C (TANKERS,				**46**			
TRANSPORT/RECON			Engines	**3.604**		Oe =	**165.8**
			Gross wt	**130,409**		Og =	**6.00E+06**
			Fuel	**95,566**		Of =	**4.40E+06**
			Max TO wt	**281,652**		Ot =	**1.30E+07**
TOTAL AIRCRAFT =		**220**					
Engine Total		Gross Wt Total		Fuel Total		Max TO Wt Total	
438		**1.05E+07**		**6.15E+06**		**2.25E+07**	

1992 USAFE AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				**338**			
			Engines	**1.566**		Fe =	**529.3**
			Gross wt	**25,595**		Fg =	**8.65E+06**
			Fuel	**10,061**		Ff =	**3.40E+06**
			Max TO wt	**54,865**		Ft =	**1.85E+07**
NUMBER OF "OTHER" A/C (TANKERS,				**50**			
TRANSPORT/RECON			Engines	**3.604**		Oe =	**180.2**
			Gross wt	**130,409**		Og =	**6.52E+06**
			Fuel	**95,566**		Of =	**4.78E+06**
			Max TO wt	**281,652**		Ot =	**1.41E+07**
TOTAL AIRCRAFT =		**388**					
Engine Total		Gross Wt Total		Fuel Total		Max TO Wt Total	
710		**1.52E+07**		**8.18E+06**		**3.26E+07**	

1995 PACAF AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				**264**			
			Engines	**1.566**		Fe =	**413.42**
			Gross wt	**25,595**		Fg =	**6.76E+06**
			Fuel	**10,061**		Ff =	**2.66E+06**
			Max TO wt	**54,865**		Ft =	**1.45E+07**
TRANSPORT AIRCRAFT(C-9,12,21,130)=				**38**			
			Engines	**3.604**		Te =	**136.95**
			Gross wt	**130,409**		Tg =	**4.96E+06**
			Fuel	**95,566**		Tf =	**3.63E+06**
			Max TO wt	**281,652**		Tt =	**1.07E+07**
NUMBER OF HELICOPTERS =				**11**			
			Engines	**1.438**		He =	**15.82**
			Gross wt	**9,723**		Hg =	**106,953**
			Fuel	**2,803**		Hf =	**30,833**
			Max TO wt	**17,388**		Ht =	**191,268**
NUMBER OF RECON A/C(E-3, C-135) =				**19**			
			Engines	**3.256**		Re =	**61.86**
			Gross wt	**90,341**		Rg =	**1.72E+06**
			Fuel	**95,383**		Rf =	**1.81E+06**
			Max TO wt	**226,415**		Rt =	**4.30E+06**
TOTAL AIRCRAFT =		**332**					
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total	
628		**1.35E+07**		**8.13E+06**		**2.97E+07**	

1994 PACAF AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				258			
			Engines	1.566		Fe =	404.03
			Gross wt	25,595		Fg =	6.60E+06
			Fuel	10,061		Ff =	2.60E+06
			Max TO wt	54,865		Ft =	1.42E+07
TRANSPORT AIRCRAFT(C-9,12,21,130)=				41			
			Engines	3.604		Te =	147.76
			Gross wt	130,409		Tg =	5.35E+06
			Fuel	95,566		Tf =	3.92E+06
			Max TO wt	281,652		Tt =	1.15E+07
NUMBER OF HELICOPTERS =				11			
			Engines	1.438		He =	15.82
			Gross wt	9,723		Hg =	106,953
			Fuel	2,803		Hf =	30,833
			Max TO wt	17,388		Ht =	191,268
NUMBER OF RECON A/C(E-3, C-135) =				19			
			Engines	3.256		Re =	61.86
			Gross wt	90,341		Rg =	1.72E+06
			Fuel	95,383		Rf =	1.81E+06
			Max TO wt	226,415		Rt =	4.30E+06
TOTAL AIRCRAFT =		329					
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total	
629		1.38E+07		8.36E+06		3.02E+07	

1993 PACAF AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				**270**			
			Engines	**1.566**		Fe =	**422.82**
			Gross wt	**25,595**		Fg =	**6.91E+06**
			Fuel	**10,061**		Ff =	**2.72E+06**
			Max TO wt	**54,865**		Ft =	**1.48E+07**
TRANSPORT AIRCRAFT(C-9,12,21,130)=				**41**			
			Engines	**3.604**		Te =	**147.76**
			Gross wt	**130,409**		Tg =	**5.35E+06**
			Fuel	**95,566**		Tf =	**3.92E+06**
			Max TO wt	**281,652**		Tt =	**1.15E+07**
NUMBER OF HELICOPTERS =				**11**			
			Engines	**1.438**		He =	**15.82**
			Gross wt	**9,723**		Hg =	**106,953**
			Fuel	**2,803**		Hf =	**30,833**
			Max TO wt	**17,388**		Ht =	**191,268**
NUMBER OF RECON A/C(E-3, C-135) =				**19**			
			Engines	**3.256**		Re =	**61.86**
			Gross wt	**90,341**		Rg =	**1.72E+06**
			Fuel	**95,383**		Rf =	**1.81E+06**
			Max TO wt	**226,415**		Rt =	**4.30E+06**
TOTAL AIRCRAFT =		**341**					
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total	
648		**1.41E+07**		**8.48E+06**		**3.09E+07**	

1992 PACAF AIRCRAFT EQUIVALENCY CALCULATIONS							
NUMBER OF FIGHTER/ATTACK A/C =				**270**			
			Engines	**1.566**		Fe =	**422.82**
			Gross wt	**25,595**		Fg =	**6.91E+06**
			Fuel	**10,061**		Ff =	**2.72E+06**
			Max TO wt	**54,865**		Ft =	**1.48E+07**
TRANSPORT AIRCRAFT(C-9,12,21,130)=				**47**			
			Engines	**3.604**		Te =	**169.39**
			Gross wt	**130,409**		Tg =	**6.13E+06**
			Fuel	**95,566**		Tf =	**4.49E+06**
			Max TO wt	**281,652**		Tt =	**1.32E+07**
NUMBER OF HELICOPTERS =				**16**			
			Engines	**1.438**		He =	**23.01**
			Gross wt	**9,723**		Hg =	**155,568**
			Fuel	**2,803**		Hf =	**44,848**
			Max TO wt	**17,388**		Ht =	**278,208**
NUMBER OF RECON A/C(E-3, C-135) =				**17**			
			Engines	**3.256**		Re =	**55.35**
			Gross wt	**90,341**		Rg =	**1.54E+06**
			Fuel	**95,383**		Rf =	**1.62E+06**
			Max TO wt	**226,415**		Rt =	**3.85E+06**
TOTAL AIRCRAFT =		**350**					
Engine Total		Gross Wt Total		Fuel Wt Total		Max TO Wt Total	
671		**1.47E+07**		**8.87E+06**		**3.22E+07**	

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13. ABSTRACT *(Maximum 200 words)*

The Hazardous Materials (HazMat) Pharmacy has been designed as an environmentally friendly vehicle to handle, store, dispense, track, recycle, and dispose of hazardous materials in the Air Force. This thesis effort proposed a method in which valuable feedback for the pharmacy can be obtained. Because it is still in the early stages of implementation, there has been little feedback on the pharmacy. An activity index that uses a variable most closely associated with the generation of hazardous waste in a MAJCOM is proposed. Using an aircraft maintenance related variable, like maximum take-off weight, the fluctuations in mission over time can explain a portion of the reductions over the same time. The additional reductions can then be attributed to pollution prevention efforts, including the HazMat pharmacy. By comparing the remaining reductions in pharmacy commands to non-pharmacy commands, the difference can be explained by the pharmacy. A notional analysis using this technique was conducted and the initial indications of pharmacy performance are encouraging. { TC "Vita" \f C \l "1" }

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