STRATEGIC CONSOLIDATION OF MEDICAL WAR RESERVE MATERIAL (WRM) EQUIPMENT UNIT TYPE CODE (UTC) ASSEMBLAGES

THESIS

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Abstract

This thesis analyzes the strategic consolidation of medical WRM equipment UTC assemblages located within the contiguous United States. Following a 2003 consolidation assessment, the Air Force Medical Logistics Office (AFMLO) consolidated some of the medical UTCs at three Consolidated WRM Storage and Deployment Centers (CSDC) located at Kelly Field Annex, Travis AFB, and Charleston AFB. While many UTCs were consolidated at that time, currently only 17 of the possible 142 equipment UTC assemblages are entirely consolidated at one of those three locations. After adding three additional bases as possible consolidation locations, this study attempts to minimize the cost of full consolidation and discusses the benefits and limitations of consolidation. Using a linear programming model designed to minimize the one-time transportation cost of consolidation, this study calculates the minimal cost based on three separate scenarios: single base, dual base, and multi base consolidation, each with unique constraints and risk factors to consider. In addition to providing the final consolidation location(s) and the transportation cost associated with that solution, the exact movement of each UTC from every base of origin to consolidation destination is generated as well.

Dedication

This work is dedicated to all those who laid the foundation for future research

If I have seen further it is by standing on the shoulders of Giants

- Isaac Newton

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I would like to express my gratitude to my advisor, Dr. William Cunningham, for his expertise in guiding me through this research. I also would thank Lt Col Daniel Mattioda for providing valuable insight as both a reader and supervisor. Lastly, I would like to express the deepest gratitude to my ENS2-13M classmates, whose inspiration, dedication, and ability to provide hours of laughter and distraction made it possible to maintain appropriate motivation and perspective during my tenure at AFIT.

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I. Introduction

Background

In a Lessons Learned document from OPERATION ENDURING FREEDOM (OEF) and OPERATION IRAQI FREEDOM (OIF), fragmented UTC deployment and poor In-Transit Visibility (ITV) throughout theater were identified as an issue, specifically with medical War Reserve Material (WRM) assemblages (Cooper, 2005). The Air Force Surgeon General requested a study from the Air Force Logistics Management Agency (AFMLA) to evaluate possible solutions to include analysis of costs and benefits of centralizing storage of medical WRM.

The outcome of that study created three Consolidated WRM Storage and Deployment Centers (CSDC) at Kelly Field Annex, Travis AFB, and Charleston AFB to serve as central storage and deployment locations for all contiguous United States (CONUS) WRM Unit Type Code (UTC) assemblages considered in the study, specifically 31 Aeromedical Evacuation (AE) and Expeditionary Medical Support (EMEDS) System UTCs (Appendix A). However, based on current data only 17 of the total 142 UTCs stored within the contiguous United Stated are currently consolidated entirely within those 3 locations.

Objective

This study serves as an extension of the 2003 medical WRM consolidation study and attempts to analyze the costs and benefits of expanding the consolidation to include more of the 142 UTCs in use. Along with determining the minimized cost of consolidating the material at a single, dual, or multi-base location(s), this study also provides the specific movements of each UTC from base of origin to final consolidation point.

Along with the results for the particular set of data used in this study, the optimization model developed has the potential for future use a tool for queries of the same nature. Since the solution provided is based on a data set captured at a single point in time, any changes made to UTC locations or quantity require modifications to the input data used in the model to determine the optimal path for consolidation.

Assumptions:

Due to time constraints and availability of data, assumptions are needed to complete this research and remain within the scope of the project. Many of these assumptions should be addressed prior to initiating action based on the recommendations of this study.

- Any manning and support equipment used to inspect or maintain UTCs at the current warehouse locations is available to be transferred to one or more consolidation point(s).
- As in the 2003 study, this study does not consider the effect of consolidation on training for all equipment UTCs if units comply with the frequency of training outlined in AFI 41-106 (Cooper, 2005).
- All UTCs previously removed from the 2003 study are considered eligible for consolidation. This captures all UTCs located within the CONUS to include pilot unit, line purchased, and rescue squadron assemblages.
- Current warehousing space is obtainable from the owning installation of any potential consolidation point, or land is made available on the site for the construction of a warehouse facility at an existing military installation.
- Transportation costs are fixed and no "time-value-of-money", inflation, or other financial adjustments are made in the study and all costs are based in 2013 dollars.
- The total requirement for WRM is at the appropriate level and no elimination of assemblages is considered during the course of this study.
- All assemblage locations listed on the Medical Resource Letter (MRL) are current and accurate and all material is positioned at the base as indicated (not currently deployed or missing).

Limitations and Constraints

This study is limited to only active duty CONUS based assets and does not consider any assets currently located through United States Air Forces in Europe (USAFE), Pacific Air Forces (PACAF), or Air National Guard (ANG) locations. Initially active duty USAFE and PACAF locations were included as separate areas of interest for consolidation, but after speaking with the Wright-Patterson Freight Management Office it was determined that currently there is no method to acquire international transportation cost estimates without utilizing the services of a freight broker to obtain quotes. Since the use of linear programming in this study requires cost estimates for every possible movement between each of the bases within a given area of interest, a broker would need to obtain approximately 120 individual quotes before the research could be completed for USAFE and PACAF locations. After speaking with a representative at an international freight brokering service, it was decided that international transportation cost data collection would prove to be too arduous to continue at this time.

The list of possible consolidation locations is also limited in this study to only 5 Aerial Ports of Embarkation (APOE) and Kelly Field Annex. These locations are the deployment locations for many current operations and would provide the fewest points of contact for a deployment tasking. Kelly Field was included due to the large amount of material currently stored at the location as well as the abundant space available for future consolidation. In addition, Kelly Field is co-located with the reserve 433d Airlift Wing, providing C-5 availabilities often used for current deployment operations.

This study does not consider any assets located at Air National Guard locations. Due to the differences in deployment procedures, if equipment UTCs are not co-located with their respective units the deployment procedures would become more complicated and could potentially create additional logistical concerns if the unit is tasked.

This study does not analyze the impact on manpower caused by consolidation. As discussed further in Chapter 2, it is expected that the total manpower requirement would decrease once the assets are consolidated, but due to lack of data the quantitative analysis is not included. This limitation is discussed further in the recommendations section in Chapter 5.

Additionally, this study does not attempt to calculate a payback period as seen in a previous WRM consolidation study (Skipper et al., 2008). Discussed further in Chapter 5, there is a lack of appropriate deployment data needed to conduct a potential future cost savings based on past usage. In addition, due to the nature of medical WRM taskings, it was decided no "standard package" could be used to estimate future deployment requirements. Currently all medical WRM assemblages are selected individually for a deployment as the requirement is determined and UTC selection often contains large variability between each deployment operation. If a deployment package containing a standard set of UTCs is created in the future, the tool created in this research could serve as a method to determine a payback period based on a number of standard deployments.

The next chapter will review past research conducted on consolidation and the use of linear programming to establish legitimacy for the methods used. Chapter 3 will step though the methodology and describe how this study conducted the data analysis. Chapter 4 provides the results of the analysis, which are then discussed in Chapter 5 along with any recommendations and conclusions.

II. Literature Review

Chapter Overview

This chapter attempts to validate the decision to consolidate WRM by reviewing past research done in the area of consolidation and the expected benefits associated with material consolidation. This chapter also reviews the past use of linear programming as a decision making tool and determines the appropriateness of its use in this study. Finally, it reviews two studies that deal specifically with WRM consolidation and discusses the results and methodologies used in each study.

Consolidation Application and Benefits

A 2005 study titled "Floating Stock in FMCG Supply Chains" researched the effects of placing "floating stock" in a supply chain in advance of retailer demand (Geerten et al., 2004). The study expressed that "a well-known result is that centralization or pooling can reduce inventories if demands are uncorrelated" and the researchers hope "that by advanced placement we can reduce non-moving inventories, shorten lead time and increase reliability" (Geerten et al., 2004, p. 2).

Geerten (2004) used qualitative and quantitative techniques as part of the research. A conceptual model allowed for a qualitative comparison between four distribution concepts that differ in inventory deployment, and the use of simulation as the main method for quantitative analysis.

The results of this study suggest the use of floating stock being "partly pushed into the supply chain, without determining the exact destination for each product beforehand . . . may lead to lower storage costs and a shorter order lead time, without a decrease in reliability" (Geerten et al., 2004, p. 12).

The use of WRM consolidation at an APOE is very similar to the study above concerning pre-positioning inventory further in the supply chain without determining the exact destination, and likely similar results of decreased storage costs and shorter lead time are expected.

In a military context, the concept of lead time would translate to how quickly the assets are able to be deployed to the required location. A military study conducted in support of Canadian Forces found "deployment cost and time are impacted by the composition of the pre-positioned manifest" (Ghanmi & Shaw, 2006, p. 1345). Through the use of 50,000 simulated 3-year intervals, the use of pre-positioning specific heavy assets resulted in a savings of $450,000 and 7 days with respect to historical baselines.

Ghanmi & Shaw (2006) reaffirms the results that pre-position inventory will result in shorter lead-time for required material. Currently the in-transit time for medical UTCs, once tasked from base of origin to the required APOE is approximately 72 hours, and this lead-time should be reduced through consolidation based on the findings of Ghanmi & Shaw (2006).

One of the most widely studied benefits of inventory consolidation is the effect on required inventory levels to maintain a determined service level through the use of the Square Root Law, "a result which asserts that the total inventory in a system is proportional to the square root of the location at which product is stocked" (Maister, 1976, p. 124). When applied, this law suggests less inventory is required after consolidation, and in the context of WRM would also result in a decrease in required warehousing space and manpower requirements since both are correlated with total amount of material.

While there is an expectation of cost savings through inventory reduction by consolidation, one common concern with the consolidation of inventory is the effect on increased transportation costs (Das, 1997). Das' (1997) "Role of Inventory and Transportation Cost in Determining the Optimal Degree of Centralization" determined the complete centralization of inventories at one facility is only optimal if no distribution is required, but "the higher the transportation cost in relation to inventory costs, the greater is the decentralization" (Das, 1997, p. 178).

Das (1997) suggests that as inventory is decentralized due to higher transportation costs the inventory should be located more closely to the customer demand. However, since the WRM consolidation points considered in this study are located at an APOE, this forward positioning of inventory is being placed nearer the customer demand and as such the increase in transportation costs discussed in Das' (1997) study would not be applicable and would suggest complete consolidation.

Uses of Linear Programming

The use of linear programming is used widely throughout transportation research including production inventory, job scheduling, production distribution, and investment analysis. Appropriate use of linear programming also allows "good financial decisions concerning facility location to minimize total transportation costs for the entire system" (Adlakha & Kowalski, 2009, p. 41).

Cost minimization through linear programming can be used in a "facility location problem that seeks to locate a number of production plants and distribution centers so that total operating costs for the distribution network are minimized" (Pirkul & Jayaraman, 1998, p. 869). The location of WRM consolidation sites is also similar to a maximal covering location problem where by using linear programming seek the objective of "locating warehouses to minimize the costs of distribution" (Church & ReVelle, 1974, p. 101).

Linear programming is also used to address medical response capability for ambulance location and relocation models for the past 30 years. The first models proposed were integer linear programming formulations that ignored any stochastic considerations of ambulance availability when using purely deterministic models discussed (Brotcorne & Laporte, 2003, p. 451).

Security Forces WRM Consolidation

In 2008, the Air Force Institute of Technology conducted a Security Forces WRM consolidation study titled "Forward Positioning and Consolidation of Strategic Inventories". This study considered specific AETC Security Forces' UTCs and attempted to provide insight, including benefits and limitations, regarding whether to move forward with consolidation (Skipper et al., 2008). Due to the similarities in the study concerning Air Force WRM consolidation, the methodology and results of this study will be briefly discussed.

The methodology in the Security Forces WRM consolidation study was primarily quantitative analysis using linear programming. Seven UTCs across 12 AETC bases were considered. Transportation cost estimates were obtained for each possible movement. Finally, the one time consolidation cost, in a single and dual base scenario, was minimized. Although on a much larger scale, the Security Forces study and this research conduct very similar methodology.

The expected benefits of WRM consolidation are also similar between these two studies and include inventory holding cost reduction, reduction in transportation costs, reduction in manpower requirement, improved reaction time involved in deployment of UTCs to overseas conflict locations, and an increase in both inspection and storage standardization (Skipper et al., 2008).

Previous Medical WRM Consolidation

An internal 2003 Air Force study entitled "Evaluation of the Recent Deployments of Expeditionary Medical Assets" followed a OIF/OEF Lessons Learned document that cited fragmented UTC deployment and poor In-Transit Visibility (ITV). This study highlights the many intrinsic benefits of WRM consolidation, including reduction in number of deployment points of contact, increasing the possibility of meeting a 15 short-ton requirement for dedicated airlift, improved standardization of construction and maintenance of UTCs, and increase proximity of strategic airlift (Overstreet, 2003).

Although the benefits of the 2003 study and this research remain very similar, the methodologies for how to consolidate material were quite different. Specifically looking at how transportation costs were estimated, the researcher consolidated the UTCs based on proximity to the coast when considering a dual base option. For example, "all the UTCs at Keesler AFB were shipping to the East Coast rather than calculating the mix of material needed at either coast" (Overstreet, 2003, p. 13). This research attempts to provide quantitative analysis and specific UTC movements based on the recommendations and expected benefits of previous research on medical WRM consolidation.

Chapter Summary

The use of linear programming within transportation problems and the benefits of consolidation are both well documented areas of research. This literature review validates the motivation and methodology of this research through the many previous studies in both areas.

Through consolidation, medical WRM gains increased ITV by having a single office of primary responsibility (OPR) and deploying assets from a single Aerial Port of Embarkation (APOE). Deploying all assets from a single location also increases the possibility of meeting the 15 short-ton requirement for dedicated airlift and allow for further increased ITV.

The reduction in manpower would be seen by eliminating or transferring some or all staff currently tasked to manage the WRM assemblages stationed at their respective bases. While additional staffing would be needed at the consolidation base selected, the net effect would be a reduction in manpower due to the gained economies of scale from pooling resources. Similarly, the total storage space would decrease for all assemblages once consolidated caused by more efficient use of space once all resources are centrally located.

When a particular UTC is tasked for deployment, there is an immediate cost savings realized since the materials are already located at or nearer the APOE to be used. Additionally, under the current policy, once a UTC is redeployed it is assembled and shipped back to the original base of origin, so there is additional cost savings by eliminating the final leg of the redeployment and returning the assets to the CSDC instead.

While not easily quantifiable, there is also a very real benefit realized by the time savings gained by maintaining the WRM assemblages at or near an APOE for rapid response and tasked to deploy.

The final benefit of consolidation is the increase in standardization and materials available of a tasked UTC. By consolidating the location of UTCs, inspection, packaging, and storage will become uniform.

The next chapter will explain the methodology used to collect data and build the models used in this study serves as a transition to data analysis and results once optimization is complete.

III. Methodology

Chapter Overview

This chapter explains the process for collecting the UTC location and cost data used in this study. It also contains a detailed explanation for building each of the three models used. This chapter also serves as a transition to data analysis and results once the process of setting up the optimization models is complete.

Data Collection

The current location of all medical WRM assemblages was obtained from the Air Force Medical Logistics Office (AFMLO) from the Medical Resource Letter (MRL) current as of 19 November 2012. This letter includes the type and number of each UTC stored at every base in the Air Force. After filtering the results to only CONUS locations falling within the scope of this study there were 46 bases remaining. The MRL also provided an accurate account of the weight and number of pallets required for each of the 142 WRM assemblage types.

Many assemblages remain at each of the bases to for use as emergency response material. Specifically, all Home Station Medical Response (HSMR), Biological Warfare/Chemical Warfare (BW/CW), and Anti-Malaria/Cholera Program assemblages were excluded from considering for consolidation. There were also man portable assemblages (backpacks) which were listed as having no weight, so they were excluded as well since no transportation costs/savings can be calculated. Also, there were 5 assemblages which were not currently located at any of the 46 bases considered in this study.

After removing the UTCs discussed above, of the original 142 assemblages listed in the MRL, 103 distinct UTCs were identified for consolidation. This list included all of the original 31 UTCs that were included in the 2003 study which are still in use, along with an additional 72 UTCs that were previously excluded. Contained within those 103 UTCs were 1909 individual assemblages spread among the 46 bases. Appendix C contains a list of all 103 UTCs consideration for consolidation.

Now that the location and number of each UTC was available, the next set of data which was needed to build the LP was the estimated transportation cost to move the material from the bases of origin to each of the 6 consolidation points. Using the weights provided in the MRL, 7087 pounds was calculated as the average weight of all considered UTCs. As in the previous medical WRM study (Skipper et al., 2008), it was decided to assume each UTC weighed the same amount. This assumption allows the LP to use a single cost to ship a UTC as long as the origin and destination bases remain the same. The determined average weight is increased to 7500 pounds to account for any additional weight caused by the actual transportation material (pallets, tarps, tie downs) and any protective material needed as well.

To validate this assumption, a simple sensitivity analysis was conducted. Rates were obtained for much higher and lower weights to determine how influential the weight of the UTC would have on transportation cost. It was discovered all vendors have a minimum transportation cost that was hit quickly after decreasing the weight from 7500 pounds (in many instances 7500 pounds was already at the minimum cost), therefore minimal savings were seen by shipping lighter assemblages. It was also found that by increasing the weight, the quotes only increased slightly as long as the request remained less than the 48,000 pound maximum for a 40 foot flatbed truck. Based on the minimal cost savings from shipping lighter assemblages and the low marginal cost of shipping additional weight, the cost differences of using the true weight for each UTC are assumed non-impactful on the results of this analysis.

Using the Rate Quotation application through Electronic Transportation Acquisition (ETA), quotes were obtained to estimate the cost of moving medical equipment between all of the bases of origin to each of the six consolidation points. As mentioned above, each shipment weighs 7500 pounds, and a 40+ foot flatbed truck was the transportation method. This method was chosen because it possessed the ability to move the many types of cargo required by the different UTCs as well as remain relatively inexpensive. The maximum weight for each truck was listed at 48,000 pounds, so based on the data obtained even the heaviest UTC at 46,660 pounds would be suitable for a single truck. A sample of the cost matrix described is found in Appendix E.

With the locations of all the UTCs and the estimated cost to ship each of them between every combination of origin and destination bases identified, the linear programming (LP) model to determine a minimal cost of consolidation for all assemblages was developed.

Decision Models

This study consists of three distinct but similar decision models, each with a common objective function but very different parameters and constraints. Specifically three separate scenarios are investigated: single base, dual base, and multi base consolidation. Each scenario requires a separate approach and is discussed individually.

Shared Aspects

The objective function for each of the three scenarios remains the same and is represented by equation 1.

$$Minimize\ Z = \sum_i \sum_j \sum_k X_{ijk} C_{ijk} \quad for\ all\ i, j, k \tag{1}$$

$$i = Base\ of\ Origin$$

$$j = Destination$$

$$k = UTC\ Type$$

$$X_{ijk} = Number\ of\ k\ UTC\ to\ ship\ from\ base\ i\ to\ destination\ j$$

$$C_{ij} = Cost\ to\ ship\ a\ UTC\ from\ base\ i\ to\ destination\ j$$

The output "Z" of this equation provides the total cost to move all UTCs from each of the origin bases to the consolidation destination and is minimized by the LP model being developed. Since the assumption was made earlier that all UTC shipment costs would be treated equally, the determining factor for the cost "*C*" is only dependent on the bases of origin and destination.

There are also three shared constraints for each model that must be implemented to ensure the model is working correctly.

$$\sum_{j} X_{ik} \leq S_{ik} \;\; for\; all\; i, k \tag{2}$$

$$S_{ik} = Number\; of\; UTC\; k\; at\; base\; i$$

This first constraint (Equation 2) ensures each base is only able to ship out as much of a single UTC to any consolidation destination as is currently located at the base. For example, if Nellis AFB has 17 of a particular UTC, the total amount shipped from Nellis AFB to all of the consolidation bases cannot exceed 17. This constraint applies for each of the UTCs contained at each of the 46 bases.

The second constraint (Equation 3) that applies to all three scenarios is as follows:

$$\sum_{j} \sum_{i} X_{ijk} = \sum_{i} S_{ik} \;\; for\; all\; k \tag{3}$$

This constraint ensures all available material is consolidated. The left side of the equation sums up the total number of UTCs shipped from all origin bases to all consolidation bases and equates it to the right side of the equation which sums up the total number of a particular UTC currently located at all the bases. This constraint ensures all available material is moved to a consolidation site for each UTC.

The cost matrix contains each of the six possible consolidation bases as origin base as well, so material that does not actually move during consolidation needs to be addressed such that Equation 3 remains valid. To account for this situation, the cost of shipping from any origin base to the same base as the consolidation point was given a cost of zero. This allows the model to output a given number of UTCs as moving from an origin base (Charleston AFB) to a consolidation base (Charleston AFB) at a cost of zero.

The final set of constraints shared between all three scenarios is that all X_{ijk} must be a general integer. This eliminates the possibility of the optimal solution including fractions of UTCs or shipping negative UTCs in order to satisfy the above constraints.

Single Site

Once the data collection was complete, the single site consolidation analysis was the easiest of the three scenarios considered. First, the total number of UTCs located at each base was calculated and then multiplied by the shipping cost for a single UTC to the destination of choice. That calculation would provide the total cost of consolidation between a single base and the consolidation point, so once it was completed for each base the total consolidation cost was found. This set of calculations was run six times, one for each consolidation option since the shipping costs would differ between each destination, the results of which are discussed in the next chapter.

Dual site

When a dual site scenario was considered the problem quickly became more complex. The UTC location matrix listing current assets contained 46 bases and 103 UTCs, of which only 475 of the cells contained values. However, when considering a dual bases option this created a total of 950 decision variables since each UTC had the option of shipping to two different locations.

The constraints listed above in equations 2 and 3 also expanded when implemented into the model. Constraint 1 (equation 2) created 475 distinct constraints, one for each combination of UTC/base combinations, and constraint 2 (equation 3) also added 103 constraints. Additionally, there was a final constraint which was needed for a dual site scenario (Equation 4):

$$\sum_i X_{ijk} \leq \left(\frac{2}{3}\right) * \sum_i S_{ik} \ \ for\ all\ k, j \quad (4)$$

This constraint was included to ensure that in a two base consolidation scenario neither of the bases would contain more that 66% of any single UTC. Similar to equation 3, the right side of the equation provided the total number of a particular UTC located at all origin bases, but then when multiplied by 2/3rds would give the upper bound for a single consolidation location for that UTC.

The left side of the equation provides the total number of a UTC that is shipped from all bases of origin to each consolidation location. By comparing these two numbers and using the 2/3rd consolidation constraint (Equation 4), it is assured that neither of the bases would contain more than 66% of a particular UTC.

This constraint was added to remain in line with the risk mitigation mindset set in 2005 when AFMLO considered WRM consolidation. Specifically when considering the final three base consolidation decision, it was decided to reduce risk of single point of failure, “less then (sic) 50% of total assemblages for a particular UTC [should be] stored at a single location” (Cooper, 2005, p. 1).

Adding a third constraint for the dual base option created an additional 206 constraints in total, one for each consolidation base and UTC, bringing the total decision variables to 950 and constraints to 784. Due the limited computation powers of Excel, a more powerful statistical software package was required.

With the use of Visual Basic for Applications (VBA), the UTC location data was extracted from Excel and uploaded into the optimization modeling software LINGO. Once the objective function and constraints were created with VBA and uploaded into LINGO as well, the software program provided the minimized cost and UTC movements and exported the results into a text file (.txt). This text file was uploaded back into Excel for further analysis. A sample of the VBA code used to extract the data from Excel and create the objective function and constraints is provided in Appendix F.

One unique situation was encountered when implementing the final constraint since there were two UTCs which currently only have a single assemblage between all 46 bases. Strictly using this constraint states that neither consolidation location could have more than .66 of the UTC, but when combined with the integer constraint and the requirement to move all material there was no feasible solution. This was addressed in VBA through an additional If/Then statement to ensure that before this constraint was applied for a particular UTC there were at least 2 assemblages within the CONUS. If only a single assemblage was available for consolidation the constraint was relaxed to allow for a base to contain 100% of the UTC.

Finally, when creating each set of dual base options it was decided that only pairs of bases that are geographically separated should be considered as viable options. Similar to the risk mitigation mindset described above that dictated no consolidation location should maintain more than 66% of the total available for each UTC, if both consolidation sites are located on the same region there would still be the risk of a single event incapacitating all material.

Multi-site

Once the VBA code was written to allow LINGO to solve the created LP, making the adjustments to include a third base for consolidation only required minor revisions. The first of which was the modification of constraint 3 to the following (Equation 5):

$$\sum_{i} X_{ijk} \leq (1/2) * \sum_{i} S_{ik} \quad for\ all\ k, j \tag{5}$$

Modified only slightly, this constraint now only allows consolidation sites to contain up to 50% of a particular assemblage. As discussed with equation 4, this constraint is directly in line with Cooper's (2005) risk reduction stipulation.

When considering three consolidation options, the size and complexity of the model increases as well: the total number of decision variables increases to 1425, and total constraints to 887. As with the dual base option, this is well outside the computational limits of Excel and once again VBA was required to input the data into LINGO to generate a solution.

Once again, it was decided all three bases in a multi base consolidation solution should remain geographically separated to ensure proper risk mitigation. Therefore, each three base consolidation option would consist of a West Coast base, an East Coast base, and Kelly Field since it represents the only consolidation option not located on either coast.

Chapter 4 provides the results of the methodology described above and discusses the implications of each set of results.

IV. Results and Analysis

Chapter Overview

This chapter provides the results of the methodology described in Chapter 3 and discuss the implications of each set of results. Since this study consists of three different scenarios each producing a unique result, the results and analysis chapter also contains three distinct sections to address each scenario individually.

Single-Site Consolidation

The lowest cost option for the location for all medical WRM UTCs is Kelly Field Annex at an estimated total cost of $1,062,990 (Table 1)

Table 1 - Single Site Consolidation Cost

Base	Total Cost
Kelly	$ 1,062,990
Charleston	$ 1,223,732
Dover	$ 1,632,033
McGuire	$ 1,667,429
Travis	$ 2,308,044
McChord	$ 2,633,255

This result is not surprising after viewing two additional pieces of data: the current location of UTCs and the average cost to move material to each of the bases of origin. Due to previous consolidation, Kelly Field Annex contains 681 of the total 1909

UTCs considered for consolidation, which represents 35.7% of the total number currently located at the 46 bases considered. Since there is only cost associated with material moved during consolidation, the cost of moving all the material currently at Kelly Field was eliminated.

Another sign that Kelly Field Annex would be chosen as the single site consolidation location is based on the average shipping cost for a UTC to each of the potential sites of consolidation. Perhaps caused by the central location of the base within the CONUS or the large transportation infrastructure throughout the greater San Antonio area, the average shipping cost from all 46 bases to Kelly Field Annex was also the second lowest (Table 2).

Table 2 - Average Shipping Cost

Base	Average Cost
Charleston	$ 742.72
Kelly	$ 780.96
Dover	$ 1,026.65
McGuire	$ 1,053.52
Travis	$ 1,215.46
McChord	$ 1,216.59

One cause for concern for choosing Kelly Field as a single site consolidation point is the proximately to a currently designated APOE. If 15 short-tons of cargo are secured for a deployment than any material shipping from Kelly would meet the minimum amount to receive dedicated airlift, but for smaller taskings the UTCs would be sent to the designated APOE before final departure at an additional cost not considered in this study. A benefit of single site consolidation is the percentage of taskings which would hit the 15 short-ton limit will increase, but it is far from guaranteed and additional cost for smaller taskings may negate some of the cost savings of consolidation.

A second cause for concern with picking any location for a single site consolidation is the risk faced with storing all material at the same location. Whether from a natural disaster, inclement weather, or intentional sabotage from internal or external threats, a single event has the possibility to destroy or prevent the use of all medical WRM stored in the contiguous 48 states. This threat could affect not only the deployment mission overseas, but the potential need to use the assets in a home station response situation.

While the use of WRM is not often used for local emergencies, it may be used "to save life or prevent undue suffering when authorized by the unit commander" (AFI 41-209, 2006, p. 91). Recently, many UTCs were activated and "deployed" in response to the earthquake in Haiti, the tsunami in Japan, Hurricane Katrina, and many other earthquakes/hurricanes over the past decade. If all response assets were stored at a single location and that area was hit by such a catastrophe, medical response capabilities would be severely limited.

Dual-Site Consolidation

Eleven unique combinations of potential sites of consolidation were created for consideration such that both of the bases are not located on the same coast. Kelly Field Annex was considered geographically neutral and therefore eligible to be paired with either coast. As seen below, Kelly Field is included in all four of the cheapest options, as well as five of the first six. As discussed above, this is based on the current location of UTCs as well as the average shipping costs associated with Kelly Field. It's also worth noting that the first three options represent Kelly Field with each of the three East Coast consolidation locations; not until the fourth option is either West Coast base included (Table 3).

Table 3 - Dual Site Consolidation Cost

Base 1	Base 2	Total Cost
Kelly	Charleston	$ 580,278
Kelly	Dover	$ 712,659
Kelly	McGuire	$ 713,404
Kelly	Travis	$ 1,094,690
Charleston	Travis	$ 1,186,624
Kelly	McChord	$ 1,189,483
Charleston	McChord	$ 1,354,596
Dover	Travis	$ 1,439,960
McGuire	Travis	$ 1,456,155
Dover	McChord	$ 1,604,521
McChord	McGuire	$ 1,623,895

While storing WRM assets at two locations certainly helps alleviate some of the concern of a single event immobilizing all stored WRM, it would still be possible to affect up to two-thirds of any given UTC at a single location. While the medical response would still be able to provide assistance with the remaining assets, if an incident occurs at Kelly Field the response would still be crippled.

Using the specific results from the optimized solution which includes Kelly Field and Charleston AFB as the dual consolidation points, the total number of UTCs located at Kelly Field is 1015 of the 1909. If relying purely on the material stored at Charleston AFB available response would still be 47% of full strength.

Another point of concern with this dual base consolidation solution is the large distance between any stored assets and the West Coast. If a response was needed nearer the West Coast there would not be any material readily available for use in the region. This would also be the case for a response much further from the coast such as Guam, Hawaii, Alaska, or even Japan. While the response time in an emergency is increased by a few hours if assets were coming from Kelly Field, as with all medical emergencies, a few hours can mean the difference between life and death for those impacted.

Multi-Site Consolidation

The third and final scenario for analysis is a multi-site option. This option contains Kelly Field in all possible solutions in combination with each a West Coast and East Coast base. There are six possible combinations total, each of which is located in Table 4 with the respective consolidation cost.

Table 4 - Multi Site Consolidation Costs

Base 1	Base 2	Base 3	Total Cost
Kelly	Charleston	Travis	$ 533,939
Kelly	Charleston	McChord	$ 610,173
Kelly	Dover	Travis	$ 680,876
Kelly	McGuire	Travis	$ 682,725
Kelly	Dover	McChord	$ 757,028
Kelly	McGuire	McChord	$ 759,725

After seeing the results from the previous two scenarios, the inclusion of Charleston AFB as the second consolidation base is of little surprise. The final determination is which West Coast base to add as the third and final consolidation point.

By utilizing three bases as consolidation points it also further reduces the risk of a single event disabling a percentage of WRM assets. In fact, Charleston AFB now becomes the largest holder of WRM material with 726 of the 1909 total UTCs, representing only 38% of total inventory. In a worst-case scenario of complete incapacitation of the materials located at Charleston AFB, the medical response could still respond to an event with up to 62% of full capabilities. By maintaining assets on each coast and a central location, the initial response range is maximized while initial response time is decreased.

Chapter 5 will discuss the recommendations and conclusions on the analysis of Chapter 4.

V. Recommendations and Conclusion

Table 5 shows the ten cheapest consolidation options.

Table 5 - Consolidation Cost Summary

Base 1	Base 2	Base 3	Total Cost
Kelly	Charleston	Travis	$ 533,939
Kelly	Charleston		$ 580,278
Kelly	Charleston	McChord	$ 610,173
Kelly	Dover	Travis	$ 680,876
Kelly	McGuire	Travis	$ 682,725
Kelly	Dover		$ 712,659
Kelly	McGuire		$ 713,404
Kelly	Dover	McChord	$ 757,028
Kelly	McGuire	McChord	$ 759,725
Kelly			$ 1,062,990

Recommendations

Using the cost estimate shown in Table 5 and after discussing some of the benefits of a three base consolidation option with regards to response time and risk of a single incident eliminating a large portion of WRM assets, the best option is to consolidate the material using the constraints previously defined between three locations: Kelly Field, Charleston AFB, and Travis AFB. A sample of the specific movements for all UTCs that minimizes the total cost of consolidation is found in Appendix F. The provided solution is only applicable given the specific data that was used to run the analysis, and any modifications to the UTCs included, the number/location of all assets, or price of shipping a UTC would require a new optimal solution.

This solution also offers an opportunity which is worth discussing, namely that no trade-off analysis is needed between cost and risk when selecting this solution. A three base consolidation option provides the widest range of response as well as the lowest risk of an event incapacitating a large percentage of WRM assets, and once the model was run for each of the three scenarios it shows a three base option also provides the lowest cost option. This unique combination of lowest risk and lowest cost provides a solution which eliminates the need to try and balance risk and cost. Discussed in Chapter 2 as an expected benefit of consolidation, all material which is consolidated also benefits from being pre-positioned further in the supply chain and a time savings of up to 72 hours could be realized during all future equipment deployments.

Two other recommendations involve ensuring better data collection. As mentioned previously, there was an attempt to calculate a "payback period" which would determine the amount of time needed to offset the one-time costs of consolidation based on future transportation savings, but it was not feasible due to inadequate data. When the master list of deployments ranging from 2001-2013 was received, there were many errors, discrepancies, and missing data. Of the 1604 deployments, 680 (42%) were missing a destination location, 254 (16%) were missing document numbers that include the deployment date, and other anomalies such as listing 640 deployments in 2003 but only 11 for 2005 and 3 for 2008. The poor data quality was attributed to a lost hard drive that contained several years’ worth of data, even though an effort was made to reconstruct it from other sources.

Additionally there were many issues when attempting to determine the effect of consolidation on staffing both at origin and destination bases, and as mentioned was not included in this study. When attempting to collect the current manpower assigned to WRM at each base, it was discovered there were very few locations that were able to provide a definitive number. When discussing with AFMLO it was discovered that “We do not currently have a manpower model for WRM that we use and leave it up to the MTF (Medical Treatment Facility) and the MLFC (Medical Logistics Flight Commander) to determine what they need to effectively operate the WRM function”. While this method works well at the operational level to carry out the mission, since there is no standard or expectation for how many people are required to manage a WRM assemblage there was little to no hard data to use for analysis.

Future Research

Future research related to this study includes:

- Review of total UTC requirements to determine appropriate number of each assemblage. According to the deployment data received, which as discussed may not be accurate, the first two assemblages considered for consolidation, 885A and 885B, each only record two deployments over a 12 year period, yet stock is maintained of 8 and 15 complete UTCs, respectively. If those assemblages are representative of the remaining UTCs there is a possibility for substantial cost savings through inventory reduction.

- The effects of consolidation on manpower regarding both locations and possible savings should be reviewed if more accurate manpower determinations can be obtained.
- Finally, a similar consolidation study to this and the 2003 study should be conducted on both USAFE and PACAF WRM assets. Those additional assets should not be included in conjunction with CONUS assets for consolidation, but instead each area viewed as a separate entity within their respective areas of interest.

Summary

The creation of the CSDCs in 2005 was a first step toward full WRM consolidation, and the results on this study validate both the decision to consolidate and the three locations selected. As discussed in Chapter 2, by consolidating medical UTCs, many expected benefits include increased ITV, reduction in manpower and storage requirements, cost savings during deployment and reverse logistics flows, increased standardization in maintenance and inspection, and reduced response time to in-theater requirements. This study expanded the research by including many UTCs previously excluded as well as provided a cost minimization tool to optimize the movements which was not utilized previously.

Appendix A – 2003 Consolidation UTCs

	UTC	NEW UTC	UTC TITLE	BULK	Over-Sized	UTC TOT
1	FFBAT	FFBA1	MED BIOLOGICAL AUGMENTATION TM	1.7	0.0	1.7
2	FFCCA		MED CRIT CARE AIR TRNS TM EQUIP	0.2	0.0	0.2
3	FFCCS		MED CCATT SUPPORT PKG	2.2	0.0	2.2
4	FFCCU	FFCC1	MED 4-BED INTENSIVE CARE UNIT	9.2	0.0	9.2
5	FFCPA		MED COLLECTIVE PROT SPEARR	2.3	0.0	2.3
6	FFCPB		MED COLLECTIVE PROT EMEDS BASIC	2.4	0.0	2.4
7	FFCPC		MED COLLECTIVE PROT EMEDS+10	2.5	0.0	2.5
8	FFCPD		MED COLLECTIVE PROT EMEDS+25	2.5	0.0	2.5
9	FFCPW		MED COLLECTIVE PROT WDS	0.8	0.0	0.8
10	FFEE1		MED EMEDS BASIC EQUIP MOD2 INC1	6.7	0.0	6.7
11	FFEE2		MED EMEDS +10/AFTH-EQUIP INC2	26.9	6.2	33.1
12	FFEE3		MED EMEDS +25/AFTH-EQUIP INC 3	12.7	4.8	17.5
13	FFEE4		MED EMEDS BASIC RESUPPLY	0.8	0.0	0.8
14	FFEE5		MED EMEDS +10/AFTH RESUPPLY	0.8	0.0	0.8
15	FFEE6		MED EMEDS +25/AFTH RESUPPLY	1.0	0.0	1.0
16	FFEE7		MED EMEDS/AFTH-SURG AUG SUPPLY	0.5	0.0	0.5
17	FFEE8		MED SPEARR EQUIPMENT	0.0	2.2	2.2
18	FFGKT	FFGKQ	MED THORACIC/VASCULAR SURG TM	1.0	0.0	1.0
19	FFGL1	FFGLC	BEE NBC TEAM	2.7	0.0	2.7
20	FFGL2	FFGLD	MED PREV&AERO MED TM 1 PAM ADV	0.1	0.0	0.1
21	FFGL3	FFGLF	MED PREV&AERO MED TM2 PAM BSC	0.2	0.0	0.2
22	FFGL4	FFGLG	MED PREV & AERO MED TM 3 SUST	0.9	0.0	0.9
23	FFGRL		MED GLOBAL REACH LAYDOWN TM	1.0	0.0	1.0
24	FFMFS	FFMF1	MED MOBILE FLD SURGICAL TM	0.3	0.0	0.3
25	FFQDM		AES INFLIGHT KITS 1	1.6	0.0	1.6
26	FFQL1		AES AE LIAISON TEAM EQUIP PKG	0.0	5.1	5.1
27	FFQM1		AES MASF-10 EQUIP PKG	0.0	10.2	10.2
28	FFQM2		AES MASF AUG EQUIP PKG	0.0	8.9	8.9
29	FFWDS		MED WATER DISTRIBUTION SYS WDS	2.7	0.0	2.7
30	FFEP1	FFEPE	MED EMEDS/AFTH-EXPED CRIT CARE	0.9	0.0	0.9
31	FFQCY	FFQN1	AES AE OPERATIONS TM EQUIP PKG	0.0	0.0	0.0

Appendix B – 2013 Consolidation UTCs

UTC	Description	UTC	Description
885A	Hospital Surgical Expansion Package (HSEP)	904J	En Route Patient Staging System Support Package
885B	Hospital Medical Expansion Package (HMEP)	904K	En Route Patient Staging System Resupply
885G	CT Scan Team	905A	Medical Support Package
885H	Ancillary Care Team	912C	SOF Surgical Primary Response Equipment
885I	Critical Care - 4 Bed	912D	SOF Surgical Electrical Equipment Augmentation
885J	Med Radiology Augmentation Team	912H	SOF Base Medical Support - Air Trans Treatment Unit
887A	AE Inflight Kits	912K	SOF Medical Element Augmentation Equipment
887B	AE Inflight Kit Resupply	912L	Casualty Evacuation Module
887D	Stacking Litter System	912M	SOF Surgical Sustainment Equipment
887E	Electronic Health Record (EHR)	912N	SOF Critical Care Evac Primary Response Equipment
887H	Critical Care Air Transport Team (CCATT) Adult Resupply	912O	SOF Rapid Response Deployment Kit
887I	CCATT Pediatric/Neonatal	912P	SOF Physiology Equipment
887J	CCATT Support Pkg.	912Q	SOF Critical Care Evac Augmentation Equipment
887N	Critical Care Air Transport Team (CCATT) Adult	912R	SOF Extended Reach Medical Equipment
887O	CCATT Pediatric Augmentation	912W	SOF Irregular Warfare
887R	Patient Isolation Unit	915G	Medical Global Reach Laydown Team
893C	Expeditionary Blood Support Center	915H	Air Transportable Clinic
893J	Expeditionary Blood Transshipment System	915I	Medical Theater Epidemiological Equipment Team
902A	Expeditionary Medical Decontamination Equipment	916E	ADVON Team Equipment Package
902B	NBC Defense Tm Equip (MNBC)	916F	PAM Team Sustainment
902C	Biological Augmentation Equipment	917A	Medical Behavioral Health Equipment
902G	Radiation Crisis Response Team	917B	Mental Health Rapid Response Team
902H	RAD/NUC Surveillance Equipment	917C	Pediatrics Team
902J	Infectious Disease & Biological Warfare Team	917D	Neurosurgical Augmentation Team
902K	Contagious Casualty Management - CCM	917E	Otorhinolaryngology Team
902L	RAD/NUC Surveillance Aug Equipment	917F	Ophthalmology Augmentation Team Equipment
902M	RAD/NUC Laboratory Equipment	917G	Thoracic Vascular Team
902N	RAD/NUC Laboratory Aug Equipment	917H	Urology Team Equipment
902O	RAD/NUC Dosimetry Equipment	917I	Expeditionary Dental Clinic
902P	RAD/NUC Dosimetry Aug Equipment	917J	High Altitude Air Drop Mission Support
903A	Oxygen Support Package	917L	GYN Team
903B	AE Oxygen Support Package	917P	Oral Surgery Team
903C	AE Contingency Support Package	917Q	Optometry Equipment Set
903I	AES MASF-10 Equip Pckg (MASF-10)	917R	HR-Peds and OB
903K	Pediatric and Geriatric Support Package	938A	EMEDS Basic
903L	AES MASF Aug Equip Pckg (MASF AUG)	938B	EMEDS +10
903O	AE Operations Team Augmentation Equipment Package	938C	EMEDS +25
903U	Patient Loading System	938D	EMEDS Resupply, Basic
903V	AES AE Liaison TM Equip Pckg	938E	EMEDS Resupply +10
903X	Spt Cell Equip Pkg	938F	EMEDS Resupply +25
903Y	AE Operations Tm Equip Pkg.	938G	Mobile Field Surgical Team (MFST)

903Z	AE Command Sq Equip Pkg	**938J**	Expeditionary Critical Care Team
904A	CASF Expendable Medical Supplies	**938K**	Expanded Capability Infrastructure
904B	25 Bed CASF Basic Equipment Package	**938M**	Water Distribution System
904C	CASF Operational Equipment Package	**938P**	HRT Basic
904D	25 Bed CASF Tent Package	**948A**	CP SPEARR
904E	Deployable Maintenance Equipment Package	**948B**	CP EMEDS Basic
904F	En Route Patient Staging System 10	**948C**	CPEMEDS +10
904G	En Route Patient Staging System Equipment PKG - 50	**948D**	CP EMEDS +25
904H	En Route Patient Staging System Expendable PKG - 50	**948E**	CP Water Distribution System
904I	En Route Patient Staging System Facility PKG - 50 Bed	**948F**	Collectively Protected Hospital Surgical Expansion Package
		948G	Collectively Protected Hospital Medical Expansion Package

Appendix C – Sample of Transportation Costs

Base	Andrews	Barksdale	Beale	Buckley	Cannon
Charleston	$ 527	$ 663	$ 2,334	$ 743	$ 743
Dover	$ 514	$ 970	$ 2,334	$ 1,309	$ 1,326
Kelly	$ 1,996	$ 493	$ 1,597	$ 710	$ 527
McChord	$ 1,906	$ 1,170	$ 863	$ 743	$ 743
McGuire	$ 514	$ 1,017	$ 2,334	$ 1,328	$ 1,344
Travis	$ 1,928	$ 1,170	$ 537	$ 906	$ 986

Appendix D – Sample of VBA Code

Objective Function

```
For j = 1 To numdestinations
   For i = 1 To numbases
      Currentcost = cost(DestinationNumbers(j) + 1, i + 1)
      For k = 1 To numUTCs
         If UTCbyBase(k, i + 1) > 0 Then
            Print #1, " + " & Currentcost & " * " & "X_" & _
                  cost(1, i + 1) & "_" & _
                  cost(DestinationNumbers(j) + 1, 1) & "_" & _
                  UTCbyBase(k, 1);
         End If
      Next k
   Next i
Next j
```

Constraint 3

```
For k = 1 To numUTCs
   For j = 1 To numdestinations
   Print #1, "[dest_" & cost(DestinationNumbers(j) + 1, 1) & "_" & UTCbyBase(k, 1) & "]  ";
      For i = 1 To numbases
         If UTCbyBase(k, i + 1) > 0 Then
            Print #1, " + " & "X_" & _
                  cost(1, i + 1) & "_" & _
                  cost(DestinationNumbers(j) + 1, 1) & "_" & _
                  UTCbyBase(k, 1);

         End If
      Next i
      If numdestinations = 2 Then
         If TotalUTC(k) >= 2 Then
            Print #1, "<=" & 0.67 * TotalUTC(k) & ";"
         Else
            Print #1, "<=" & TotalUTC(k) & ";"
         End If
      End If
      If numdestinations = 3 Then
         If TotalUTC(k) >= 3 Then
            Print #1, "<=" & 0.5 * TotalUTC(k) & ";"
         ElseIf TotalUTC(k) = 2 Then
            Print #1, "<=" & 0.67 * TotalUTC(k) & ";"
         Else
            Print #1, "<=" & TotalUTC(k) & ";"
         End If
      End If
   Next j
Next k
```

Appendix F – Sample of Optimal UTC Movements

Origin	Destination	UTC	Quantity	Cost
CHARLESTON	TRAVIS	902K	1	$ 1,170
CHARLESTON	TRAVIS	903Z	1	$ 1,170
DAVISMONTHAN	KELLY	912L	2	$ 659
DAVISMONTHAN	KELLY	912O	4	$ 659
DAVISMONTHAN	KELLY	915H	2	$ 659
DOVER	CHARLESTON	904G	1	$ 527
DOVER	CHARLESTON	904H	2	$ 527
DOVER	CHARLESTON	904I	2	$ 527
DOVER	KELLY	915G	2	$ 1,263
DYESS	KELLY	915H	2	$ 538
DYESS	KELLY	916E	1	$ 538
EGLIN	CHARLESTON	915H	2	$ 527
EGLIN	CHARLESTON	916E	1	$ 527
EGLIN	CHARLESTON	938G	2	$ 527
EGLIN	CHARLESTON	938J	2	$ 527
EGLIN	KELLY	903A	1	$ 585
ELLSWORTH	CHARLESTON	916E	1	$ 743
ELLSWORTH	KELLY	915H	1	$ 743
FAIRCHILD	TRAVIS	905A	1	$ 621
FAIRCHILD	TRAVIS	915H	1	$ 621
FEWARREN	KELLY	903L	1	$ 743
FEWARREN	KELLY	903O	1	$ 743
FEWARREN	KELLY	903V	1	$ 743
FEWARREN	KELLY	904F	1	$ 743
FEWARREN	KELLY	915H	1	$ 743
GRANDFORKS	KELLY	915H	1	$ 743
HILL	TRAVIS	905A	1	$ 541
HILL	TRAVIS	915H	3	$ 541
HILL	TRAVIS	916E	1	$ 541
HOLLOMAN	KELLY	915H	2	$ 527
HOLLOMAN	KELLY	916E	1	$ 527
HURLBURT	CHARLESTON	912C	2	$ 527
HURLBURT	CHARLESTON	912D	2	$ 527
HURLBURT	CHARLESTON	912H	1	$ 527
HURLBURT	CHARLESTON	912K	1	$ 527
HURLBURT	CHARLESTON	912L	7	$ 527
HURLBURT	CHARLESTON	912M	2	$ 527

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Vita

Captain Chad M. Whitson was born in Red Wing, Minnesota in 1985. He received his High School diploma from Red Wing High School in June 2004. He entered undergraduate studies at the United States Air Force Academy, where he graduated with a Bachelor of Science degree in Systems Engineering Management and received his commission in May 2008

His first assignment went spent on a one-year Medical Logistics Internship in the Wright-Patterson AFB 88th Medical Group. From 2009 through 2011, Captain Whitson served as the Medical Logistics Flight Commander in the 355th Medical Support Squadron at Davis-Monthan AFB. Captain Whitson entered the Graduate School of Engineering and Management, Air Force Institute of Technology in September 2011, graduating with a Masters Degree in Logistics and Supply Chain Management in March 2013. Upon graduation, he will be serving as the Medical Logistics Flight Commander within the 52nd Medical Support Squadron in Spangdahlem, Air Base, Germany.

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14. ABSTRACT
The purpose of this research was to improve the effectiveness of organizational meetings, thereby reducing the waste from ineffective meetings. Specifically, this thesis sought to answer three research questions addressing the essential elements for effective meetings, the benefits from productive meetings, and the information and skills critical to conducting meetings. The research questions were answered through a comprehensive literature review, and the use of the Delphi Technique. However, the solicitation of meeting materials from 16 Malcolm Baldridge National Quality Award winners and 90 Fortune 1,000 firms provided additional information. Seven experts, representing Air Force and industry, participated in two rounds of the Delphi Technique. The research identified the need for a concise and realistic length management tool to instruct managers on how to conduct effective meetings. Further, research highlighted that few corporations in industry have such a tool, even among those firms recognized as being the pinnacle of quality.

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