RESOURCE CONSOLIDATION AND LOCATION DECISION MAKING FOR DAMAGED AND DISABLED AIRCRAFT RECOVERY

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ABSTRACT

This research provides a cost benefit analysis and potential consolidation method for the US Air Force's Aircraft Crash Damaged or Disabled Aircraft Recovery (CDDAR) Program. The goal is to provide a better management system and to maximize utilization of scarce resources. The study considers location consolidation options and seeks to minimize costs. This initial study of CDDAR consolidation uses a heuristic approach and identifies a potential of $25 million in savings for three of the most costly CDDAR items. Future research using optimization methods on a broader number of items has the potential to find additional savings for the US Air Force.

INTRODUCTION

The U.S. Air Force's resources are becoming more constrained every year. This research effort is an attempt to provide a cost benefit analysis and potential consolidation method for the Air Force's Aircraft Crash Damaged or Disabled Aircraft Recovery (CDDAR) Program in order to provide better management and maximum utilization of scarce resources. If we contrast CDDAR capabilities, we discover that the capabilities of the Air Force CDDAR program are unparalleled around the world, when it comes to flexibility and adaptability to overcome unforeseen circumstances. However, to maintain this capability the Air Force must be a good steward of taxpayer dollars and develop the most efficient system possible. This initial study of CDDAR consolidation uses a heuristic approach to find a potential of $25 million in savings for three of the most costly CDDAR items. Future research using optimization methods on a broader number of items has the potential to find additional savings for the US Air Force.

Aircraft Mishaps and Crash Recovery

Mishaps can occur because of pilot error, weather, equipment failure, maintenance malpractice, and even sabotage. The processes that are used to recover an aircraft vary by each scenario and aircraft type. Responders may not have everything they need to recover an aircraft in every situation, and the ability to forecast an incident is a fleeting task, so you don't know when, or where, a mishap is going to occur. The two distinct phases of an aircraft mishap are initial response and recovery. The Crash Damage or Disabled Aircraft Recovery program deals with both phases after an aircraft mishap. The initial response phase exposes people and equipment to immediate dangers from aircraft fire, gases, harmful vapors, and solid particles that are released into the environment from the mishap. The recovery phase of an aircraft mishap exposes personnel to “fibers and inhalable dusts as aircraft parts are moved, modified by cutting, breaking, twisting, or hammering” [2, pg. 253]. Therefore, response and recovery actions take special training, equipment, and risk awareness so that injury and illness are mitigated to the greatest extent possible. The Air Force has a requirement for all flying units to maintain a CDDAR capability. There is some common equipment that can be used across different types of aircraft, but specific equipment may also be required for recovery operations based on the specific incident. The requirement for CDDAR capability at each location (Air Force Base) was developed because it is impossible to accurately predict the timing and location of an aircraft mishap.

A mishap is defined by the Air Force as an unplanned occurrence or series of occurrences that result in certain levels of damage or injury. In the civilian sector, the National Transportation Safety Board investigates aircraft mishaps. Individual carriers are held responsible to move their aircraft from airfields when they are impeding airport operations. When looking at the private sector, we must not only discern the differing techniques and practices between public and private sectors, but we must also account for what the private sector does better or more efficiently. Identifying the rationale for any intentional differences; and, where possible, determining whether best practices and lessons learned can be exchanged and applied to the benefit of the military.

Problem Statement and Research Objective

How should the Air Force resource the Crash, Damaged, or Disabled Aircraft Recovery Program? What theoretical lens might be applied to gain insight into this problem? Can a regionalized approach be implemented? And if so, how far can the equipment be from the required location on demand? The current method for accomplishing this objective requires analysis to determine a relevant methodology and means to improve its effectiveness and affordability.

LITERATURE

Risk Pooling

Risk pooling is “often achieved by consolidating a product with random demand into one location” [4, pg. 2]. The research on risk pooling demonstrates there are great benefits to achieving statistical economies of scale. This term has many other forms such as economies of scope and the term used sometimes in the military is “economies of force” [5]. Gerchak [4] researched “how demand variability affects the consequences and benefits of risk pooling.” His findings show that, as intuition would suggest, the greater the demand variability the larger the benefits are for risk pooling [4, pg. 3], and the greater savings in inventory from using fewer locations. Additionally, Sheffi [7] states that forecasts are much better at the aggregate level and there are several strategies to deal with the uncertainty in a forecast. One of the strategies is product variability reduction. In product variability reduction, the options are reduced and “the smaller number of options allows better risk pooling, lower variability and thus better forecasts and lower overall costs.” Sheffi [7] further states that “in order to pool the forecasting risk, companies should manage inventory centrally” [7, pg. 15]. Further research by Simich-Levi et al. [8] shows that the three critical points on risk pooling include: 1) Centralizing inventory reduces both safety stock and average inventory in the system. In a centralized distribution system, whenever demand from one market is high and demand in another market is low, resources originally allocated for the low demand market can be reallocated to the other. 2) The higher the coefficient of variation, the greater the benefit obtained from centralized systems because the coefficient of variation is standard deviation/average demand. 3) The benefits of risk pooling depend on the behavior of demand from one market relative to another. The research on risk pooling shows that centrally managed inventory and reducing product options available helps to decrease forecasting risk and increases the cost benefits of risk pooling. This suggests that a centrally managed inventory (CDDAR equipment package) might be developed and located in only a few locations. Then as Simchi-Levi suggests, moving equipment from the lower demand locations, reducing equipment redundancies, and lowering inventory and inspection costs for the Air Force.

Using a similar philosophy, the International Air Transportation Association (IATA) has coordinated with the International Airlines Technical Pool (IATP) to pool aircraft recovery equipment. IATA analyzed the requirements and concluded that 11 lifting kits, strategically placed around the world would meet the requirements for the entire industry. The 11 proposed kits were developed and the cost-sharing by the airlines was based on rate of exposures and operational areas. This methodology was determined to be equitable by the airlines participating in the pool [3]. This risk pooling resulted in a "lifting kit consisting of six 23-tonne pneumatic lifting bags, two 73-tonne large-extension hydraulic jacks and one set of tethering equipment, stored on pallets and ready for immediate shipment to any accident location together with skilled operating personnel". These kits are now available at "Australia (Sydney), Brazil (Rio de Janeiro), France (Paris), India (Bombay), Japan (Tokyo), South Africa (Johannesburg), United Kingdom (London), and United States (Chicago, Honolulu, Los Angeles and New York)" [3]. This pooling arrangement has served the industry well; it takes into account the high cost of equipment and pools the risk across the industry. If an airline is not a member of IATP, they are charged for the use of the kit and the requestor is required to pay for transporting the kit to the sight of the incident.

Air Force Audit Agency Reports

The Air Force Audit Agency [1] conducted 12 local area audits on the Crashed, Damaged, or Disabled Aircraft Recovery Program from 5 Dec 05-24 Aug 06. The major themes in the local audits are:

1- Local instructions were not consistent with Air Force regulations
2- Program managers did not properly identify, complete, and record training
3- Managers did not accurately validate equipment authorizations
4- Equipment authorizations exceeded actual requirements
5- Coordination was lacking for training and equipment handling

An additional Air Force level audit dated 27 November 2006 covered 16 locations and was performed to determine if Air Force personnel properly accounted for CDDAR equipment, properly established equipment authorizations, and effectively implemented CDDAR program requirements. Overall, the program was found to be in need of improvement, and audit calculated that "the Air Force maintains over $18.6 million of on-hand CDDAR equipment with an additional $5.4 million on order".

METHODOLOGY AND DATA

A strategic look is required to position assets with relationship to risk regarding probability of occurrence and its impact based on duration of an airfield closure. The methodology employed in this research is primarily quantitative in nature with qualitative background information collected through telephone interviews and electronic mail. Data was collected using various systems including Logistics

Installations and Mission Support-Enterprise View (LIMS-EV), Air Force Equipment Management System, and aircraft technical data. To capture as many perspectives as possible, research efforts examined multiple Major Commands (geographic regions) and civilian industry policies and procedures. In addition to policy review, aircraft recovery experts within the Air Force and the civilian community were interviewed for their perspective on the issue.

In order to recover an aircraft, special equipment is required. This equipment includes lifting bags, air distribution manifolds, slings, and cables. Some of the additional equipment required includes air compressors, shackles for connecting cables, and dunnage to support lifting bags and other equipment for de-bogging aircraft from uneven surfaces. The equipment consists of items common to all aircraft as well as aircraft-specific items. The equipment list in Table 1 is not an exhaustive list, but it illustrates the numerous equipment requirements that exist for aircraft recovery. The three highlighted items were the items considered for consolidation in this study.

Table 1. Representative CDDAR Equipment List

Item	**Approx Price Per**
Portable Generator	$ 2,500.00
Shackles 55T (load meter)	$ 900.00
Shackles 35T (load meter)	$ 600.00
Sling Saver Shackles 35T	$ 600.00
Shackles 25T	$ 350.00
17K Tie Down Straps	$ 75.00
4” X 4” X 8’ Plastic Timbers	$ 21.00
Tifor Tether Kits (3 plates, 1 tirfor, 9 stakes, 1 cable, 1 handle)	$ 1,400.00
20K Belly Band Strap	$ 300.00
Air Bags 15T	**59,788.00**
Air Bags 26T (less required at KC-135 (4) and smaller units)	**$ 69,735.00**
4’ X 8’ Plywood	$ 25.00
Consoles	$ **6798.00**
40T Sled (with turntable)	$ 100,000.00
Remote Reading Load Meter 50T	$ 6,000.00
Remote Reading Load Meter 25T	$ 3,000.00

Assumptions and Limitations

Two key assumptions were made regarding this research: 1) This research applies to Air Force Base home station (not deployed) CDDAR capabilities. Home station capabilities are what the host unit is able to provide at the current local operating area. 2) The data gathered during the timeframe of this research project is not time dependent. That is to say that this data is representative of data that would be collected in a future study of similar scope holding all else equal. The research conducted was quantitative and qualitative in nature and involved personal, telephonic, and electronic mail interaction. Further research could be accomplished to look at manning, training, equipment lists by aircraft system. This research focused on equipment utilization and placement.

Regionalization Location Methodology

To select locations for regionalization a factor rating methodology is used. Key factors include: aircraft type assigned to the base, active duty personnel availability, number of runways, distance from other regionalization locations, and ability to control decisions from an operations center. Locations selected for regionalization of equipment are selected first on access to transport aircraft and then by active duty location. C-130 and C-17 aircraft are the tactical airlift choices for transport. The C-130s bases must be able to be directly tasked through the control center. Table 2 describes aircraft and locations.

Kit Contents Methodology

The standard quantity of airbags and consoles per airframe is based on Air Force authorization data and has been confirmed by CDDAR subject matter experts for fighter, bomber and cargo aircraft types. For this research, the authorized quantity per aircraft type is considered the quantity demanded per event.

Table 2. Regionalization Candidate Aircraft and Air Force Base (AFB)

C-130	C-17
Dyess AFB, TX	Charleston AFB, SC
Little Rock AFB, AR	Travis AFB, CA
	McChord AFB, WA
	Joint Base McGuire-Dix-Lakehurst, NJ
	Dover AFB, DE

Table 3 shows the authorized equipment by aircraft type as derived from Air Force authorizations. Using the highest number required per equipment item, a standard regionalized location inventory level is established. This enables any regionalization location to have equipment to respond to any aircraft incident type with the maximum quantity of CDDAR equipment required.

Table 3. Authorized Equipment by Aircraft

	Quantity Required		
Aircraft	**26-Ton**	**15-Ton**	**Consoles**
C-5	11	4	15
C-17	8	6	14
C-130	1	4	5
KC-135	8	8	16
B-1	2	2	4
B-52	14	0	14
U-2	0	5	5
A-10	0	4	4
F-15	0	3	3

F-16	0	4	4
MAX # in column	14	8	16

This maximum inventory level is then multiplied by the number of regionalization locations in the CONUS. Total numbers required for regionalization at 5, 6, or 7 different sites have been calculated and are listed in Table 4.

Table 4. Total CONUS Equipment Inventory

Max Quantity Required For Single Incident Response

Number of Regionalization sites	**26-ton 14**	**15-ton 8**	**Console 16**
5	70	40	80
6	84	48	96
7	98	56	112

Kit Consolidation Methodology

Determining where to pull inventory from to stock at a potential regionalization location was determined based on shortest distance to travel from inventory pull locations. Ragsdale [6, pg. 76] states this type of heuristic as "always ship as much as possible along the next available path with the shortest distance (or least cost)." To determine shortest distance between bases Google Maps was utilized to calculate driving distances. Once driving distances were calculated then the following steps were taken:

1) Pull equipment items from nearest base until zero balance on that item
2) Once zero, go to next nearest base until demand at regional site is satisfied
3) If only one item is pulled from a base look at next base for a single consolidated shipment

Another method that could have been used is linear modeling. Ragsdale provides guidance on how using heuristics could solve this type of transportation and location problem versus a linear model, using Solver in Microsoft Excel or other optimization methods [6]. Using a heuristic may not be perfectly optimal but it does provide a method with rigor that is repeatable. The heuristic also provides a timely development process to solve the problem. This method is similar to other classic transportation and facility location problems not only in civilian but military applications alike. Similar models have been used in military application research including consolidation of security forces equipment for deployment purposes [9]. Extensions of this research are currently being conducted to determine the effectiveness of this heuristic approach and to potentially provide an optimal solution.

RESULTS

Regionalization Location Solution

Five locations were selected for regionalization: McChord AFB, Travis AFB, Dover AFB, Charleston AFB, and Dyess AFB. Joint Base McGuire-Dix-Lakehurst and Little Rock AFB were not selected based on proximity to other regionalization location alternatives. In addition, Dyess AFB was selected over Little Rock AFB because of multiple aircraft types at the location, enabling the regionalized location to service two different aircraft types at one location versus Little Rock AFB with only one.

Kit Contents and Consolidation Solution

The kits required at each regionalization site will contain 8 15-ton airbags, 14 26-ton airbags and 16 consoles (Table 1). The kits are able to handle any single aircraft mishap. In addition, this inventory also provides additional capability if multiple incidents occur requiring other equipment. Total inventory required to be transferred to regionalization sites included, 26 26-ton airbags, 7 15-ton airbags and 10 consoles. This inventory was sourced based on the heuristic developed in the methodology section. The inventory was sourced from 11 different Air Force bases as listed in Table 5. This solution minimized distance traveled to the regional locations to minimize cost of transportation.

Table 5. Equipment Sourcing Location

Equipment	# Moved	CHARLESTON	DOVER	DYESS	MCCHORD	TRAVIS
26-Ton	26	4-Robins 1-Moody 1-Patrick	2-Andrews	3-Altus 1-Cannon 3-Tinker 1-Barksdale	6-Fairchild	4-Edwards
15-Ton	7	2-Robins		2-Cannon	2-Mountain Home	1-Edwards
Console	10	4-Robins		4-Cannon	2-Fairchild	

Table 6 shows the inventory levels at regionalization locations prior to consolidation, which was used to calculate the quantities required to be transferred for regionalization.

Table 6. Inventory Before Consolidation

Equipment	Required Inventory at Each Location	CHARLESTON	DOVER	DYESS	MCCHORD	TRAVIS
26-Ton	14	8	12	6	8	10
15-Ton	8	6	10	6	6	7
Console	16	12	24	12	14	22

Table 7 shows the additional inventory required by location to meet at least 100% of the inventory requirements at each of the regionalization locations. The total equipment requirement needing transport is 26 26-ton, 7 15-ton, and 10 consoles.

Table 7. Additional Inventory Required at Consolidation Locations

Equipment	Total # to Move	CHARLESTON	DOVER	DYESS	MCCHORD	TRAVIS
26-Ton	**26**	6	2	8	6	4
15-Ton	**7**	2	-2	2	2	1
Console	**10**	4	-8	4	2	-6

After inventory was transported to regionalization locations (Table 5), the final inventories shown in Table 8 meet the minimum requirement for consolidation with some locations having more inventory than required.

Table 8. Inventory Post Consolidation

Equipment	Min Requirement	CHARLESTON	DOVER	DYESS	MCCHORD	TRAVIS
26-Ton	14	14	14	14	14	14
15-Ton	8	8	10	8	8	8
Console	16	16	24	16	16	22

This post consolidation inventory list shows additional inventory at Dover and Travis due to the fact that both bases already had more inventory than was required for regionalization of some equipment items. This excess equipment is able to be turned-in or sold according to Air Force regulations. This also eliminates inventory costs and inspection requirements associated with excess inventory. After regionalization at five locations, the total US inventory of CDDAR equipment includes 70 26-ton airbags, 40 15-ton airbags, and 80 consoles. Table 9 shows inventory costs.

Table 9. CONUS Regionalization Inventory Cost

Nomenclature	Authorized	In Use	Unit Price	Total Inventory Cost
Console	80	80	$ 6,798.00	$ 543,840.00
15-ton	40	40	$ 59,788.00	$ 2,391,520.00

26-ton	70	70	$ 69,735.00	$ 4,881,450.00
				$ 7,816,810.00

Table 10 shows the current inventory cost calculations of all three equipment items across all active duty US locations totaling $32.9 million. After subtracting the regionalization inventory cost (Table 9) from the current total inventory cost, one can see this result eliminates over $25 million dollars of excess inventory. Adding in resale values and avoided maintenance expenses bolsters the savings already estimated.

Table 10. Pre-Regionalization CONUS Inventory Cost

Nomenclature	Authorized	In Use	Unit Price	Total Inventory Cost
Console	343	191	$ 6,798.00	$ 1,298,418.00
15-ton	159	149	$ 59,788.00	$ 8,908,412.00
26-ton	240	326	$ 69,735.00	$ 22,733,610.00
				$ 32,940,440.00

This solution shows the potential magnitude of cost savings that could be accomplished through a regional approach. If expanded to include all CDDAR items and the entire Air Force worldwide inventory, regionalization across the world the benefits could be even greater. Additionally, this heuristic could be used to expand this concept of operations to worldwide operations including contingency operation locations in the Middle East.

CONCLUSIONS

According to this preliminary consolidation study, the Air Force could save up to $25 million in inventory alone when a regionalization approach to CDDAR program management is implemented even for the limited scope of the study. This research focused on only three equipment items which are some of the most costly CDDAR assets The savings will only be greater when applying this methodology to other items required for CDDAR operations. However, this study is not suggesting regionalizing all assets required for CDDAR operations. There is an immediate need for equipment items specific to individual aircraft types and bases that would be financially more efficient to keep located at each base across the US. Some of these items include snatch cables, shackles, and tie straps. The three items included in this research are common across all aircraft types and are trained on by all CDDAR technicians; making them an obvious choice for consolidation. In addition, the savings in inventory reductions could come at a price of readiness. Therefore, the IATA has calculated their risks using occurrence rates based on different locations, aircraft types, and traffic, and we recommend the Air Force similarly calculate risks using the same methodology. The price of Air Force readiness cannot be calculated with the data currently available. Another finding of this research unveiled there is no current tracking method to capture when CDDAR equipment is used during an aircraft incident. Therefore incident occurrence rates need to be determined by aircraft type and base location, and currently the Air Force does not collect this data.

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