A DELPHI STUDY TO DETERMINE VARIABLES FOR PREDICTIVE MICAP MODELING

GRADUATE RESEARCH PROJECT

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Abstract

Since the inception of the United States Air Force in 1947 it has cycled through many supply chain management organizational structures. Additionally, in the early 1950’s the Air Force developed a major supply chain management data exchange operating system. As a result, the current Air Force enterprise supply chain system does a relatively good job getting mission essential aircraft parts into their artisan’s hands most of the time. But despite their best efforts, the Air Force has proven to be unsuccessful in predicting mission essential parts needs at times for weapons systems across their enterprise, creating financial and manpower burdens across the wholesale and retail supply chain levels of operation.

This research is essentially a first step towards identifying variables to be studied in further detail. Since there is no literature or any pre-ordained list of Department of Defense predictive variables from previous studies, this Delphi study was chosen to flesh out agreement between subject matter experts and provide a compass for future studies. The researcher found that neither of the Delphi panels was able to come to any level of agreement. The researcher provides limitations and recommendations for future research.

Acknowledgements

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Jeremy L. Pankoski

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A DELPHI STUDY TO DETERMINE VARIABLES FOR PREDICTIVE MICAP MODELING

I. Introduction

"Logistic considerations belong not only in the highest echelons of military planning during the process of preparation for war and for specific wartime operations, but may well become the controlling element with relation to timing and successful operation."

-- *Vice Admiral Oscar C. Badger, USN*

Background and Problem Statement

When the Air Force was recognized by the National Security Act of 1947 as a standalone military service branch, it too inherited the burden of keeping its fleet of aircraft operational. To meet this challenge the Air Force implemented a major electronic data-exchange platform, stood up multiple supply chain agencies throughout its history and gradually developed better systems methodology to provide an ever increasing level of sustainment parts support.

The first major supply chain operations initiative the Air Force implemented was the introduction of the Standard Base Supply System in August 1965. Nearly five decades later the Standard Base Supply System remains the electronic data exchange solution for the Air Force enterprise supply chain operations. As antiquated as the Standard Base Supply System is, it remains the sole system by which aircraft parts requirements are communicated, local stock levels managed and the system that tracks retail level demand.

The second major initiative the Air Force implemented was replacing many of the individual operational base retail supply chain functions by creating regional supply chain operations called the Regional Supply Squadrons. These Regional Supply Squadrons were aligned functionally under their respective MAJCOM Combatant Commanders vice local Wing Commanders. This gave each of the Combatant Commanders operational control of parts support to their fleet independent of the other Combatant Commanders needs. The third major initiative of the Air Force was to dissolve the Regional Supply Squadrons and create two Air Force enterprise supply chain organizations called the Mobility Air Forces Logistics Supply Center and the Combat Air Forces Logistics Supply Center that both aligned under the direct command of the new Air Force Global Logistics Supply Center. The Mobility Air Forces Logistics Supply Center had aircraft parts support oversight and responsibility for all Mobility Air Forces airframes to include C-5 Galaxy, C-130 Hercules, C-17 Globemaster III, KC-135 Stratotanker and the KC-10 Extender. The Combat Air Forces Logistics Supply Center had aircraft parts support oversight and responsibility for all Combat Air Forces airframes to include F-16 Fighting Falcon, F-15 Strike Eagle and A-10 Wart Hog. The creation of these two logistics supply centers aligned all of the mobility airframes under one center and all combat airframes under another center allowing for consolidated global parts management and deconfliction of aircraft parts priorities across all combatant commands. The most recent initiative the Air Force implemented was dissolving the Air Force Global Logistics Supply Center Command section. According to RAND Corporation, The Budget Control Act of 2011 (Pub L. 112-25) directed cuts in defense spending where the AF divvied out 4,500 manpower cuts to AFMC (Robert S. Tripp, 2012). While the

Air Force Global Supply Center command structure was eliminated to meet the Budget Control Act objectives, the Mobility Air Forces Logistics Supply Center and the Combat Air Forces Logistics Supply Center remain intact and are functionally aligned under the new Air Force Sustainment Center.

Despite the many initiatives discussed above, the Air Force is still unable to predict mission essential aircraft parts shortages at time. This study evaluates open ended ideas solicited from two groups of Air Force Supply Chain subject matter experts regarding initiatives that could be used to help predict mission essential aircraft parts shortages before they occur.

Research Question

The study research question thus follows:

What initiatives can be identified by a panel of subject matter experts to predict future mission essential aircraft parts shortages before they occur?

Research Objective and Focus

The current Air Force enterprise supply chain system does a relatively good job getting parts into their artisan's hands most of the time. However, the Air Force still operates in a reactive nature for many mission essential parts needs. Despite their best efforts, the Air Force has proven to be unsuccessful in predicting mission essential parts needs at times for weapons systems across their enterprise, creating financial and manpower burdens across the wholesale and retail supply chain levels of operation. The intent of this is study is to identify initiatives through a Delphi Study that can be used to predict future mission essential parts shortage situations before they occur. Some of the

Delimitations of the study may be the identification of the Subject Matter Expert (SME) group members. To mitigate this delimitation the Air Force's 735th Supply Chain Operations Group will assist with identifying participants for subject matter expert Delphi panels. The first Delphi panel group will be Senior Non-Commissioned Officers and Civilians at the Retail Supply Chain levels of operation. The second Delphi panel group will be Mission Support Group and Maintenance Group Commanders or equivalents.

Benefits and Implications of the Research

This study has potentially significant impacts in the way the Air Force views its ability to predict future mission essential parts shortages across its enterprise. All Major Commands and Supply Chain Operations Groups alike could benefit from this study as it could save numerous resources and reduce our "parts chasing" culture through a predictive mission essential parts (MICAP) initiative. The results of this study however will only be the first step. A follow on study will need to be conducted to actually model the variables identified in this study to determine the absolute validity of their predictive abilities.

II. Literature Review

Providing aircraft sustainment parts support to the Air Force's aging fleet of airframes can be a daunting challenge at times. What's more, today's financially constrained fiscal environment and diminishing industrial vendor base makes predicting/forecasting sustainment parts shortages more critical. The Air Force no longer has the financial luxury to pack its shelves full of spare parts in anticipation of a parts need. The Air Force has settled on low service levels of parts support and consider the extra cost burden at the time of purchase to be better than the cost of procuring, storing, and maintaining an item for a long period. This simply illustrates the inability to predict parts shortages resulted in the acceptance of parts shortages to achieve lower inventories and reduced costs. There has been no past research regarding the Air Force's ability to implement a predictive sustainment part model. Therefore, this literature review first focuses on the history and development of the Air Force's Supply Chain Structure and IT systems that have led to increased supply chain efficiency and responsiveness over time. The author then focuses on two concepts from current literature that in theory provide a methodology to rapidly respond or predict sustainment parts shortages followed by some of the trending issues affecting the Air Force's Supply Chain.

History of Air Force Supply Chain Management Systems

According to Brigadier General A.A. Riemondy, in 1962 most Air Force base supply accounts were managed by a mix of manual, punch-card, or computerized inventory control systems where eleven different systems were in use, each designed autonomously by the major commands to fit the peculiarities of their accounting equipment. Proliferation of nonstandard base supply systems, designed with minimal Headquarters Air Force control, restricted the Air Staff in establishing meaningful supply policy (A.A. Riemondy, 1970). Lack of standardization prevented measurement of support effectiveness and required base supply organizations that were costly in manpower lending to the decision to develop a centrally controlled standard supply inventory system that was announced in 1962, when it became obvious that the Air Force had outgrown first generation computers (A.A. Riemondy, 1970).

In August 1965, the U.S. Air Force embarked on a significant new program. During the following year, 110 Air Force bases were converted to the USAF Standard Base Level Supply System operating on UNIVAC 1050-11 Electronic Data-Processing Systems (K. B. Codlin. W. H. McGlothlin, 1968). The 1990 RAND Corporation study went on to state this activity represents the first Air-Force-wide implementation of a centrally designed, computer-based logistics support system. This centralization, for the first time, made it possible for the Air Force to implement policy decisions and improve system designs across the Air Force enterprise. This also led to the creation of a standard supply organization. A single standard organization with standardized operations, system products, forms, and training now serves all bases where prior to 1963 the number of different supply organizations paralleled the systems in existence (A.A. Riemondy, 1970). Currently, the management and ownership of the Standard base Supply System resides in the Logistics Readiness Squadron's under the Chief of Supply (Logistics Readiness Squadron Commander) at each of the retail supply locations.

The Air Force Legacy Standard Base Supply System remains the sole enterprise solution at the retail supply chain level for supply chain management and has benefited from continuous major and minor modifications over the decades. One of the biggest modifications to the Standard Base Supply System happened in the early 1980's. According to Kenneth Faulhaber, the 1960s and 1970s methodology for calculating retail base level inventory policy used two factors. The first factor was the priority of a customers demand on a scale of 1 to 4 where 1 is the most urgent priority. The second factor used to calculate inventory policy was the number of demands an item, both consumable and reparable, experienced since the date of its first demand regardless of how long ago the first demand occurred. This methodology led to approximately 50% of the grounded aircraft due to parts shortages for low cost consumable parts (Kenneth B. Faulhaber, 1982). To address significant low cost, consumable parts shortages that represent approximately 80% of all assets stocked at the retail base level supply accounts accounting for only about 15% of inventory investment for spares (Kenneth B. Faulhaber, 1982) it was directed the Standard Base Level Supply Systems methodology change. In 1982 the Department of Defense Directive 4140.44 and supporting instruction 4140.45 identified the range of stock leveling methodology in the Standard Base Level Supply System be replaced with methodology to consider economics of operation as well as demand history (Kenneth B. Faulhaber, 1982). The resulting change in the Standard Base Supply System was a major overhaul to the 1960s and 1970s methodology. The new methodology calculated the range of stock and the depth of stock using an economic cost driven approach coupled with a weighted factor to consider customer priorities on the previously identified 1 through 4 scale. To expound, the range of stock now considered demand history, order costs, holding costs, order and ship time and unit price when considering the inventory policy to stock or not stock each asset. If the cost to stock was greater than the cost not to stock, then no stock level was established and the part was ordered only as a demand was realized (Kenneth B. Faulhaber, 1982). Furthermore, according to Kenneth Faulhaber, to ensure the methodology was not purely driven by economic cost driven calculations the customer priorities (1 through 4) were assigned weights to ensure high cost items were not assigned a stock level. Logic was added to always stock priority 1 parts after the first aircraft grounding incident for that part. Finally, depth of stock calculations used for the new methodology used the simple Wilson lot size formula (Kenneth B. Faulhaber, 1982) for calculating economic order quantities:

$$EOQ = \frac{Y\sqrt{DailyDemandrate * VariableStockageObjectives * Unit\,Price}}{Unit\,Price}$$

$$WhereY = \frac{2 * CostToOrder}{HoldingCostRate}$$

The 1982 Standard Base Level Supply System methodology previously discussed calculated the retail base level inventory policy. Today's Standard Base Supply System currently maintains the necessary logic to track demand and place requisitions when retail stock on reparable and consumable sustainment parts drop below the inventory policy.

The next major upgrade to the Air Force enterprise supply chain management was the implementation of the Readiness Base Leveling D035E system. The D035E system now uses similar methodology to the Standard Base Supply System but on a global scale. The D035E system is a standalone system that allocates the worldwide requirement among base users and depot facilities incorporating multiple business rules: adjusted stock levels (min, max, fix), repair cycle time, percentage of base repair, item cost, order and ship time and forward stock locations (Silver, 1998). According to AFMAN 23-110 volume 3, part 9, prior to the establishment of Readiness Base Leveling, the process of determining base and depot Peacetime Operating Spares levels was an independent process operated at each base and depot location. The levels were not related to readiness or to the D200A requirement (i.e., the desired number of assets in the world). The Readiness Base Leveling concept was developed to remedy these shortfalls (AFMAN 23-110 Publication). Readiness Base Leveling uses base and depot historical usage data including adjusted stock levels, to determine the allocation of the worldwide requirement - an allocation that will result in the greatest decrease in base level expected backorders (AFMAN 23-110 Publication).

The methodology to derive the inventory policy and control of inventories of consumable sustainment parts in the Air Force is a simple EOQ model. The methodology employed to derive the inventory policy and control the inventories of repairable items in the Air Force is Mod-Metric computations. The Metric model was first developed for the Air Force and is the first practical application of multi-echelon theory (Sherbrooke, 1985). According to Sherbrooke, the basic theory has been employed in a number of models that incorporate other features such as multiple indentures of spare parts, and it provides the foundation for the repairable spares procurement policies now in use by military departments. For both the EOQ and Mod-Metric methodologies cost is a factor in both computations. In either case, considering cost could implement a less than desirable inventory policy. As Sherbrooke continues, Multi-indenture models for (s – 1, S) inventory policies, such as Mod-Metric and the Logistics Management instituted Aircraft Availability model, tend to understate expected back orders and over state expected availability of repair items (Sherbrooke, 1985).

As depicted in the previous paragraphs the Air Force has implemented management systems and methodology enabling the management of consumable and reparable sustainment parts.

Enterprise Resource Planning Systems

Over a five year period the Air Force attempted to stand up an Enterprise Resource Planning system called Expeditionary Combat Support System. According to Dr. Jamie Morin, Air Force Comptroller, the main driver behind the Air Force needing an Enterprise Resource Planning system is to meet the auditability milestones that Department of Defense leaders charged them with achieving in 2014 and 2017. The Department of Defense and the Government Accountability Office have concluded the Enterprise Resource Planning systems are the only way to centralize and track the vast quantities of DoD logistics, financial, pay and personnel data that would satisfy outside auditors. But the key attribute the Air Force Supply Chain would benefit from an Enterprise Resource Planning system would be centralized data and collaboration with the wholesale supply chains Defense Logistics Agency. Currently, when a demand is placed on a sustainment part at the retail Standard Base Supply System level, the demand for that part is only visible at the retail level. The Defense Logistics Agency currently has a fully operational Enterprise Resource Planning system that could collaborate within a real time data exchange environment if the Air Force had an Enterprise Resource Planning system of its own. The Air Force legacy 1960's Standard Base Supply System cannot communicate with the Defense Logistics Agency Enterprise Resource Planning system. The IT platforms are not compatible.

Here is an example of how the inability to collaborate and share information from the Air Force retail enterprise supply chain to the Defense Logistics Agency wholesale supply chain increases lead time and hampers parts availability. If the Air Force retail supply chain has more than one year of stock for a particular sustainment part, then each time the local maintenance unit places a demand on that part, only the retail level Standard Base Supply System realizes that demand. Over a period greater than a year the wholesale supply chain, Defense Logistics Agency, without any demand on this part has no reason to continue current relationships with suppliers for existing contracts with the vendor base. When the retail supply point exhausts their stock on this sustainment part, they turn and place another large order with the wholesale supply chain. This scenario greatly increases the lead time for the Defense Logistics Agency to get this sustainment part back on the retail shelves.

Increased Supply Chain Responsiveness through Centralization

When an Air Force unit deploys its weapon systems to the theater of operations the unit is deployed with readiness spares packages. For a war tasking, thirty days supply is typically deployed in a readiness spares package as it is assumed that there will be no re-supply for thirty days (Christopher M. Beckley, 2007). The sustainment parts that will be included in the readiness spares package is a function of historical demand data and economic factors considered by the D200A worldwide availability of each asset. According to AFMAN 23-110 Volume 1 Part 1, Chapter 14, the annual review cycle will be timed so as to conclude in time for Air Staff approval of the requirement prior to the March D200A cycle readiness spares package overlay. Additionally, the purpose of the review is to update the range of items in authorized readiness spares packages and verify the complete set of data used to compute quantities for those items. Because each branch of the military is required to stock items based on economics in accordance with Department of Defense regulation 4140.1, Materiel Management Regulation, it is this consideration of cost that drives the under estimate of expected backorders. The demand for these sustainment parts is hard to forecast and any stock out in the deployed environment will be a mission essential parts shortage.

Prior to 1990, when a deployed unit needed to replenish parts used from the readiness spares packages, the deployed unit relied solely on the in garrison supply organization to submit requisitions. The lifeline of the deployed unit was the readiness spares kit, a deployable spares package that was the forerunner of today's readiness spares package and to replenish the kits, each deployed unit would download its replenishment requirements to a tape and mail it to the home station, where the transactions would be sorted manually and downloaded to the Standard Base Supply System (Robert E. Mansfield, 2002). General Mansfield also stated this process added two weeks or more in administrative processing for weapon system spares replenishment—unacceptable in a wartime environment.

In 1990 the Air Force stood up a centralized supply chain command and control organization called the Air Force Contingency Supply Support Activity (AFCSSA). The creation of the AFCSSA centralized the receipt and consolidation to pass requirements from deployed units to sources of supply in a near real-time, automated fashion and act as a single, authoritative focal point with sources of supply (Robert E. Mansfield, 2002). General Mansfield offers further proof that AFCSSA proved its worth during Operation Desert Storm by reducing order and ship time by 10-14 days and eliminating the inefficiencies and sub optimums caused by multiple units' linking to the home station for core supply support. Although the creation of AFCSSA lead to faster resupply of deployed units aviation spare parts, it did not enable better forecasting or the ability to predict mission essential parts shortages.

The AFCSSA concept was seen as such a success story for deployed parts support, the Air Force Supply Executive Board chose to create a new command and control organization that could conceptually provide the same level of support to all MAJCOMs. In 1997 the Air Force stood up four Regional Supply Squadrons at PACAF, USAFE, ACC and AMC that were charged with direct support to their respective MAJCOM units. Under the Regional Supply Squadron concept the retail level supply organizations continued to provide organic support to their local aviation and maintenance organizations from local stock. When local stock at the retail supply level is exhausted and a mission essential sustainment parts shortage (MICAP) occurs, the Regional Supply Squadron is notified for an enterprise solution and global sourcing actions. The Regional Supply Squadrons did not enable better forecasting or prediction of mission essential parts shortages. However, they did lead to faster sourcing solutions, better communications and collaboration leveraging relationships across the supply chain at a more senior level in the organization to decrease parts shortage durations via a healthier inventory. PACAF Regional Supply Squadrons reduced mission essential parts shortages (MICAP) at Kadena Air Base, Japan, from 574 to 196, while MICAPs at Elmendorf AFB, Alaska were reduced from 420 to 224, both within the first 30 days under Regional Supply Squadron management (Robert E. Mansfield, 2002). The ACC Regional Supply Squadron decreased order and ship time by 65 percent in 1 year, reduced command excess equipment by $3M, and reduced MICAP shortages by 50% for the E-3, B-2, and HH-60 (Robert E. Mansfield, 2002).

Although the regional supply squadrons were a great success they were MAJCOM centric and did not provide an enterprise solution to supply chain management. Under the Regional Supply Squadron concept each of the MAJCOM's operated as their own distinct supply chains occasionally competing against each other for critical sustainment parts.

In an effort to create an enterprise-wide supply chain management solution the Air Force Global Logistics Support Center (AFGLSC) was created. The AFGLSC was stood up in 2007 and assisted the Air Force's depot level supply chain (Air Logistics Center) and the retail supply chains (base level). The AFGLSC is responsible for establishing and executing plans for the purchase, delivery, return, and repair and lifecycle management of materiel (Strategies, 2008). The organization also manages supply chain performance, business rules, budgeting processes and technology requirements and for the first time in its history, the Air Force has created a single organization responsible for balancing resources and requirements with an integrated focus on enterprise-wide priorities (Strategies, 2008). Gone are the days of in fighting over competing priorities. The Air Force under the AFGLSC will prioritize the enterprise solutions for each MAJCOM simultaneously and apply sourcing solutions for mission essential parts where they need to be.

In 2012 the Air Force dissolved the AFGLSC command structure and merged the AFGLSCs organization under the command of the Air Force Sustainment Center. The supply chain enterprise focus created under the AFGLSC conceptually remains the same under the Air Force Sustainment Center.

Sense and Respond Logistics

As seen in Figure 1 below, the private sector borrowed best-practice concepts in military logistics beginning in the 1960s and the Department of Defense is now implementing private sector best practices by pursuing the concepts, practices, and technologies of supply chain management (Russell, 2007). The Department of Defense took notice of the private sectors successes with supply chain transformation and created a supply chain executive position in 1998, Deputy Under Secretary of Defense for Supply Chain Integration, however a supply chain management campaign was not launched until 2003 under the Expeditionary Logistics for the 21st Century Program (Expeditionary Logistics for the 21st Century Campaign Plan, 2002).

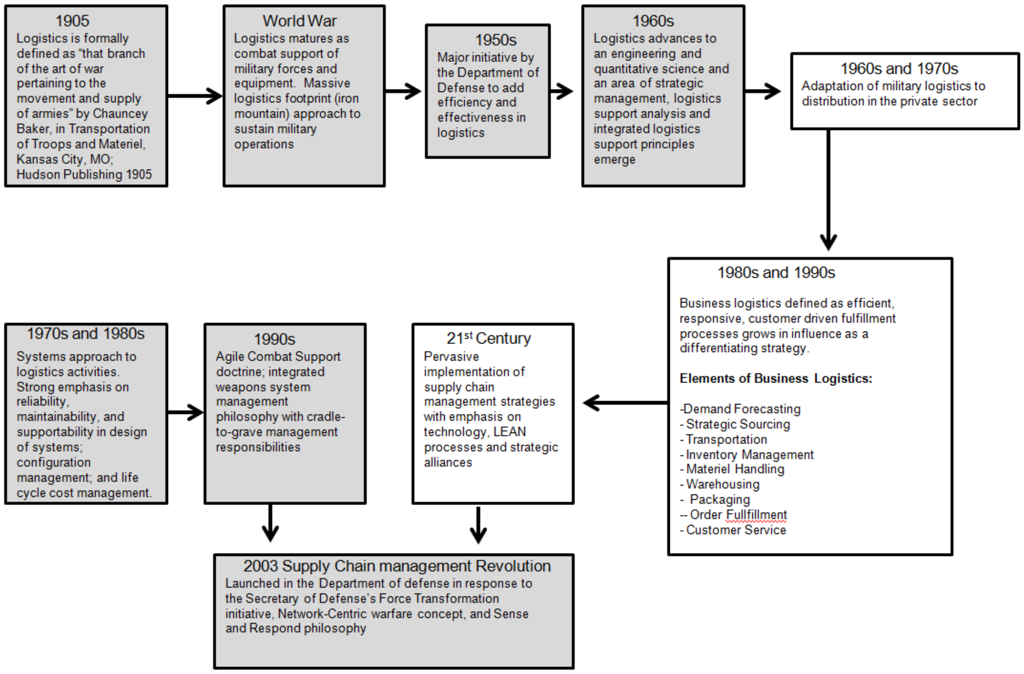


Figure 1: Evolution of Logistics Thought and Practice

Retrieved from (Russell, 2007) 30 Dec 12

According to the campaign plan, to effectively support the Expeditionary Air Force, an integrated logistics chain must establish better ways to respond to two critical warfighter questions – "Where is our part?" and "When will we get it?" Further stated by the Air Force Chief of Staff General John P. Jumper, this is no small task – and the logistics community has always met the challenge with unyielding success, innovative thinking, and unfailing reliability. General Jumper went on to say that the end of the Cold War and the shift to an expeditionary fighting mode requires that we fundamentally change the way logistics conducts business, to support expeditionary operations we must dramatically improve the efficiency of our operations (Expeditionary Logistics for the 21st Century Campaign Plan, 2002).

The Expeditionary Logistics for the 21st Century Campaign lead to an initiative in 2001, under the Secretary of Defense Donald Rumsfeld's guidance, to transform United States military capabilities resulting in the creation of the Office of Force Transformation (Russell, 2007). Under the first Director of the Office of Force Transformation, Arthur K. Cebrowski, the Office of Force Transformation focused on a guiding philosophy of the transformation which was coined Network Centric Warfare. Network Centric Warfare is a theory that relies heavily on advancements of the information age with a viable information technology backbone. Guided by the Network Centric Warfare philosophy the Office of Transformation released the Sense and Respond initiative in 2003 as a philisophical umbrella for military supply chain management as a strategy for developing supply chains with players, information systems, capabilities and protocols to respond to changing combat support requirements in the field (Russell, 2007). The Sense and Respond business philosophy was adopted by the Department of Defense but was initially created in 1992 by Stephan H. Hackel, President of Adaptive Business Designs, of the IBM Advanced Business Institute. Stephan H. Hackel served as an advisor to the Department of Defense Office of Transformation in 2003.

Historically, the Air Force employed a mass based approach to supporting the warfighter. The Air Force used the mass based approach due to the inability to forecast and predict what the warfighter would need. Consequently, supplies and sustainment parts were sent overseas in massive amounts of inventory to hedge against uncertainty in demand and supply. The Air Force subscribed to the philosophy that more is better where the mountains of supplies and sustainment parts were measured in days of supply to compensate for long lead time supply chains. This was an expensive inventory approach and clogged the transportation pipeline and ports with iron mountains. On the other hand, the Sense and Respond model would predict, anticipate and coordinate actions that provide competitive advantage spanning the full range of military operations across the strategic, operational and tactical levels of war (Transformation, 2004).

Sense and Respond is a great idea in concept, but the Department of Defense has many implementation barriers. A 2006 RAND Corporation study stated that some important technologies that are needed to enable an ultimate Sense and Respond capability are radio frequency identification (RFID), intelligent (adaptive) software agents, and an Enterprise Resource Planning Solution. The radio frequency identification technology allows for in transit visibility and hands off processing of materiel transactions. Radio frequency identification has shown glimpses of success but still has a way to go. Experience from recent conflicts is replete with incidences of large stocks en route to the theater becoming unidentifieble and their disposition delayed until they were physically inspected and combat units began to identify critical shortages, often affecting warfighting capability (Robert S. Tripp e. a., 2006). The required intelligence adaptive software agents needed for Sense and Respond Logistics are thinking, adaptive, autonomous computer based models that do not adhere to the traditional programming rule sets or code. As a result of this autonomy, agents exhibit complex social behavior, whereby one agent may attempt to "persuade" another agent to execute a particular function (Robert S. Tripp e. a., 2006). Agents typically are proactive (goal-directed and thus intentional) or reactive, have abilities to communicate or negotiate with each other, learn from experience, adapt to changes in their environments, make plans, and reason via logic game theory (Davidsson, 2004). The final requirement for Sense and Respond

Logistics is a viable Enterprise Resource Planning Solution. Unfortunately, on Oct 2012 the Air Force officially cancelled its ongoing Enterprise Resource Planning Solution program known as the Expeditionary Combat Support System. Without an Enterprise Resource Planning Solution Sense and Respond Logistics cannot be realized.

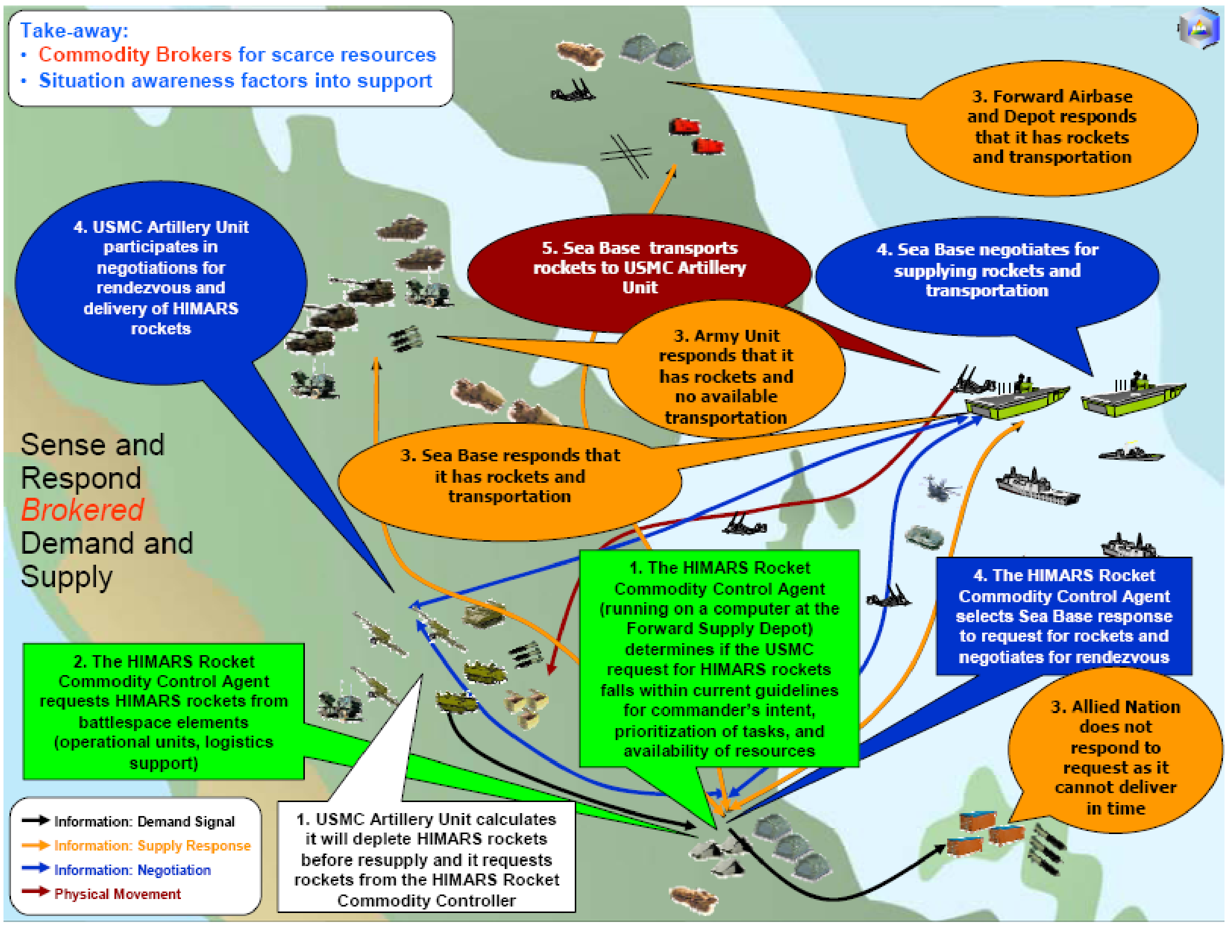


Figure 2: Notional Sense and Respond Logistics

Retrieved from Speed and the Fog of War, NDU, Needham and Snyder, Jan 09

Autonomic Logistics

Perhaps the pinnacle of the Air Force supply chain being able to predict weapons systems sustainment parts shortages is through Autonomic Logistics Systems. There is literature that supports this claim however the practical application of weapons systems with Autonomic Logistics Systems in the fleet has not yet been realized. Autonomic Logistics has been cited as a broad term used to describe technologies that predict failure in operating systems, monitor stockage levels in consumables, automatically report impending failures and order replacements without human intervention (Menotti, 2004). The first weapon system equipped with an Autonomic Logistics System the Air Force will field is the future F-35.

Figure 3: Lockheed Martin F-35 Autonomic Logistics System

Retrieved from http://www.lockheedmartin.com/us/products/ALIS.html 31 Dec 12

Autonomic Logistics Systems will not remove all facets of human interaction. These systems will primarily be the focus of real time parts failures just prior to or about to fail. This advance warning of failure will provide enough time for the part procurement and delivery to the maintainer ahead of need. This will not however replace the need for strategic planning and long term forecasting. Long-term predictions are still required for strategic planning purposes, as well as for processes with long lead times (Robert S. Tripp e. a., 2006).

Trending Issues Affecting Air Force Supply Chain Management

Over the past 60 years the Air Force has seen its weapon systems age resulting in a greater need to predict critical sustainment parts shortages. This coupled with a diminishing vendor base leading to longer lead times to purchase and acquire spare parts should be of great concern for the Air Force enterprise. Just one of the factors alone would be enough to drive any private sector organization into a sub-optimal level of customer support. That being said, the Air Force enterprise has performed admirably in the face of the many challenges.

The civilian airlines industry has the capital and support to recapitalize on their fleet of aircraft at a much greater rate than the Air Force. As such, the civilian airlines have the ability to not exceed the expected service life of the aircraft they fly. More importantly, the civilian airlines do not experience as much spare parts obsolescence as the Air Force does. When an aircraft is operated beyond its expected service life the ability to predict the next parts shortage is difficult.

Aircraft	Number	Age	Rank for the age by aircraft type
Airbus A319	55	12.8 years	On 130 airlines operating this type of aircraft United Airlines ranks 123
Airbus A320	97	14.5 years	On 225 airlines operating this type of aircraft United Airlines ranks 169
Boeing 737	15	17.8 years	On 284 airlines operating this type of aircraft United Airlines ranks 50
Boeing 737 Next Gen	224	9.1 years	On 190 airlines operating this type of aircraft United Airlines ranks 120
Boeing 747	24	17.2 years	On 92 airlines operating this type of aircraft United Airlines ranks 34
Boeing 757	155	17.8 years	On 71 airlines operating this type of aircraft United Airlines ranks 30
Boeing 767	56	15.1 years	On 105 airlines operating this type of aircraft United Airlines ranks 31
Boeing 777	74	13.4 years	On 60 airlines operating this type of aircraft United Airlines ranks 52
Boeing 787	1	0.2 years	On 8 airlines operating this type of aircraft United Airlines ranks 3
TOTAL	701	13.4 years	**The calculation of the fleet age can be approximated because it is only based on the supported aircraft**

Figure 4: United Airlines Fleet Age

Retrieved from http://www.airfleets.net/ageflotte/United%20Airlines.htm 28 Dec 12

The Air Force on the other hand continues to fly airframes well beyond expected service life driving increased sustainment costs through service life extension programs and unexpected parts breakages on parts that were supposed to last the lifetime of the aircraft.

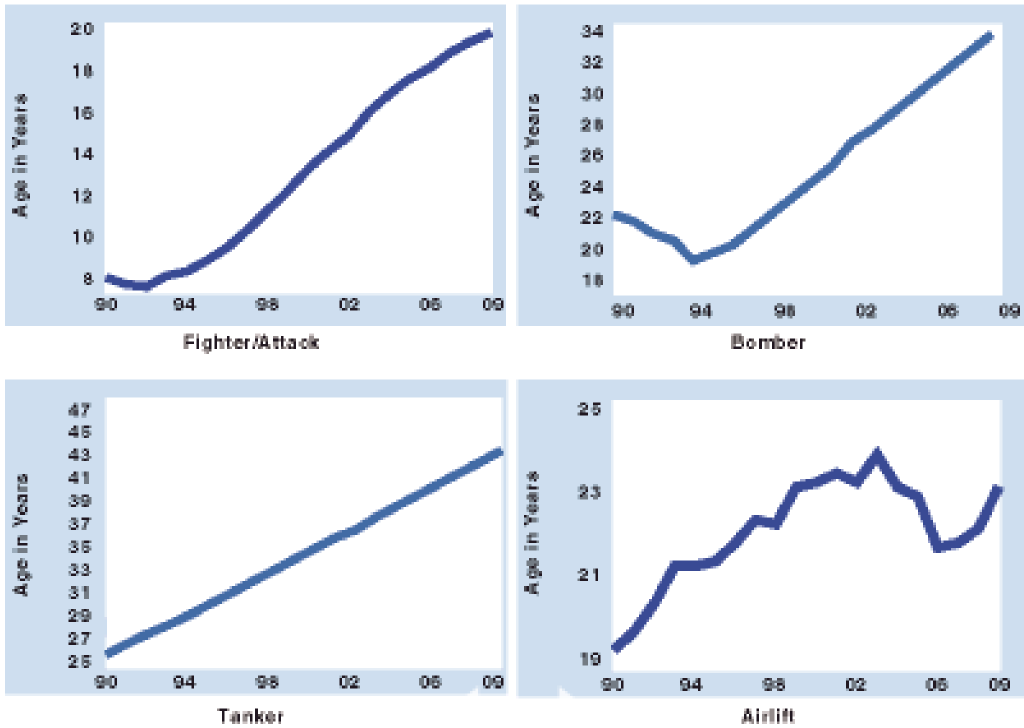


Figure 5: United States Air Force Fleet Age

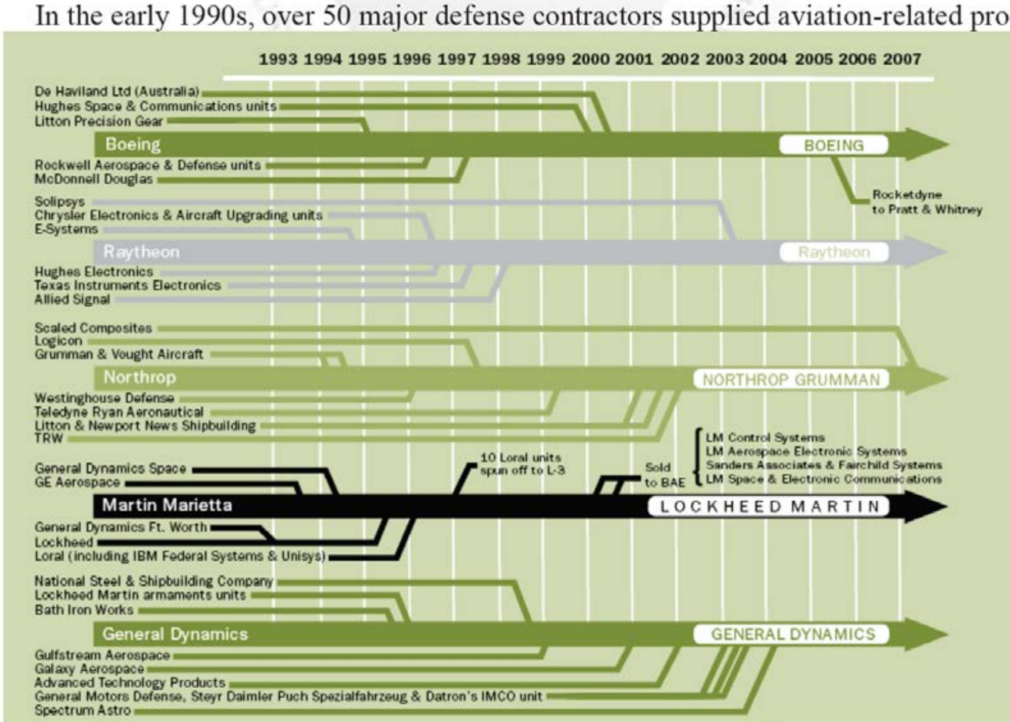
Retrieved from http://www.defenseindustrydaily.com/aging-array-of-american-aircraft-attracting-attention-0901 28 Dec 12

Previous Air Force Secretary Michael Wynne, speaking at a Washington think tank, said that the service's stay-within-its-top line bootstrap approach isn't arresting the aging aircraft problem, and the inventory age is still rising, from 23.9 years today to 26.5 years by 2012. Previous Air Force Chief of Staff General Mosely and Secretary of the Air Force Michael Wynn stated, One C-130E Hercules from the 86th Airlift Wing at Ramstein Air Base, Germany, is so old and in such bad shape it cannot safely fly. Yet Air Force maintainers must tow it around the tarmac every so often to make sure its tires don't go flat, and crank up the engines every month to make sure they still run. More than 20 percent of the service's C-130Es are grounded or have significant flight restrictions.

As the Air Force fleet ages the challenges of keeping them fully mission capable is increasingly difficult, manpower intensive and costly. When an aircraft exceeds its original service life, it has effectively outlived the life of many parts that were never expected to be replaced. The cost of replacing these parts in an effort to extend the service life is very costly and can exceed the original procurement cost of the weapon system. The Air Force plans to extend the service life of selected F-16s by 2,000 flying hours each and estimates that it will complete this work by 2022 at a cost of $2.61 billion. Comparatively, Lockheed Martin Corp. in Fort Worth, TX received a $786 million contract from Egypt for 20 F-16 Block 52s: 16 F-16Cs and 4 F-16Ds (Daily, 2012). Additionally, the A-10 fleet is in the midst of a billion-dollar upgrade in which the aircraft that the Air Force will retain are getting new wings. The new wings and structural improvements will boost the A-10's life expectancy from 16,000 hours to 20,000 hours, buying it a place in the inventory until about 2035 (Tirpak, 2011). One of the key factors to the increased cost for service life extension programs is the lack of parts availability in the industrial vendor base.

An industrial base is a system of non Department of Defense capabilities that the wholesale supply chain, Defense Logistics Agency, can contract with for sustainment parts support to meet Air Force retail end customer requirements. According to Lt Col David King, PhD, USAF, The accomplishments of today's US aircraft industrial base have their origins in investments made during and following World War II. Subsequent declines in the number of aircraft programs pursued by the US government have had a profound impact on both the number of firms and workers in the air and space industry (King, 2006). During the 1940s and 1950s, 40 different jet-fighter designs by nine different defense firms took flight (Levaux, 1998). Consequently, the Air Force, Navy, and Marine Corps procured more fighter and attack aircraft in six years (1951–56) than in the following 34 years (1957–90) (Rich, 1990). To put this in perspective, consider that between 1958 and 1979 the United States and its allies took delivery of a total of 5,195 F-4 Phantom IIs, but between 1990 and 2004, industry produced only 572 fighter aircraft for the Air Force (King, 2006). The decline in aircraft production has contributed to industry consolidation because smaller procurement quantities and fewer aircraft programs can sustain only a few firms (King, 2006) and less partners in the industry to purchase spare parts from.

In the early 1990s, over 50 major defense contractors supplied aviation-related products



Defense Industry Consolidation 1993-2007[2]

Figure 6: Defense Industry Consolidation

Retrieved from http://nation.time.com/2012/09/13/calls-for-phantom-defense-cuts-must-stop 28 Dec 12

What this means for the Air Force is longer lead times for parts support. When an airframe is going through a service life extension program, occasionally the industrial vendor base cannot respond quickly to a part that has not been manufactured for decades. The vendor who bids to make these parts will require ample lead time to re-tool their equipment, procure required aviation grade raw materials and specifications to include obtaining engineering drawings or proprietary data and possibly even reverse engineering the part.

III. Methodology

Background

The Delphi method originated in a series of studies that the RAND Corporation conducted in the 1950s. The objective was to develop a technique to obtain the most reliable consensus of a group of experts (N. Dalkey, 1963) rather than any individual experts responses. Studies have consistently shown that for questions requiring expert judgment, the average of individual responses is inferior to the average produced by group decision processes; research has explicitly shown that the Delphi method bears this out (Chitu Okoli, 2003). Delphi is an appropriate group method for this study. A study as this one has not previously been accomplished and therefore will provide an initial attempt at understanding the problem. Some literature asserts that the Delphi method is well suited as a research instrument when there is incomplete knowledge about a problem or phenomena; it works especially well when the goal is to improve our understanding of problems, opportunities, solutions, or to develop forecasts (Skulmoski, 2007). Among other high performing group decision analysis, Delphi is desirable in that it does not require the experts to meet physically (Rohrbaugh, 1979). All of the subject matter experts in this study will be surveyed by way of e-commerce (e-mail) and all responses will be held confidentially by the researcher. Conducting all of the surveys via e-mail is the simplest and most efficient manner due that all of the respondents, the sponsor and the researcher are Department of Defense, United States Air Force members.

The Delphi group size does not depend on statistical power, but rather on group dynamics for arriving at consensus among experts, thus the literature recommends

10-18 experts on a Delphi panel (Chitu Okoli, 2003). The group size of 20 per Delphi panel for each of the two groups in this study was negotiated between the researchers Air Force Institute of Technology advisor and the 735th Supply Chain Operations Group sponsor. The first Delphi panel group is comprised of Senior Non-Commissioned Officers and Civilians at the Retail Supply Chain levels of operation and the second Delphi group is comprised of officers in the rank of Lieutenant Colonel and Colonel or GS-14 to GS-15 Civilians. It is important to note that throughout the Delphi literature, the definition of Delphi subjects as it applies to who is chosen has remained ambiguous (Kaplan, 1971). The administration of this Delphi study will be through two (possibly three) phases. The first phase of the study will begin after the selection of the subject matter experts in each of the two Delphi panels.

The First Phase or brainstorming phase treats all expert respondents as individuals, not panels (R.C. Schmidt, 2001). A Delphi pilot study of the first round open-ended survey will be conducted with the intent of testing and adjusting the questionnaire to improve reliability prior to sending the round one survey to the Delphi panels. After the pilot study, the first questionnaire will be e-mailed to all Delphi panel members where they are asked to brainstorm and list at least eight factors they perceive as important to predicting future mission essential parts shortages before they occur. When all of the Delphi panel responses have been received, the responses will be consolidated by the researcher and a panel of Air Force supply chain cohorts, duplicates removed and terminology will be standardized where necessary. After consolidation of all of the Delphi panel responses, they will be categorized into manageable categories of similarity by the researcher and a panel of Air Force supply chain cohorts. Once the researcher and supply chain cohorts arrive at a consensus and appropriate categorization for all panel responses, the second questionnaire will be prepared for the second phase.

The second phase, or ranking phase will ask experts from both Delphi panels to individually rank order all of the consolidated and categorized responses from 1 to 8, where 1 = most important and 8 = least important in predicting future mission essential parts shortages. After each Delphi panel member has responded with their rank ordered lists the researcher will assess consensus for each Delphi panel using Kendall's Coefficient of Concordance (Kendall's W).

Kendall's Coefficient of Concordance

A Kendall's W of 0 would mean there is no agreement among Delphi panel members and a Kendall's W of 1.0 would mean the Delphi panel members have perfect agreement. Table 1 below shows the interpretation of the confidence in the agreement of group ranks related to a calculated Kendall's W.

Table 1: Interpretation of Kendall's W

Table 1: Interpretation of Kendall's W		
W	Interpretation	Confidence in Ranks
0.1	Very weak agreement	None
0.3	Weak agreement	Low
0.5	Moderate agreement	Fair
0.7	Strong agreement	High
0.9	Unusually strong agreement	Very High

Retrieved from (Schmidt, 1997) 2 Apr 13

Unlike Pearson's Correlation Coefficient, Kendall's W is an appropriate and easier test to run because it does not make any assumptions regarding the nature of the probability distribution and therefore, Kendall's W can handle many distinct outcomes (Rohrbaugh, 1979). If Kendall's W is not greater than or equal to 0.70 a third round survey could be administered to the expert Delphi panels in an effort to gain a greater consensus. Further clarifications and attempts for agreement can be sought through a third round. However, compared to the previous two rounds, only a slight increase in the degree of consensus can be expected from a third round (Chia-Chien Hsu, 2007). Furthermore, Delbeq suggests that two to three iterations are sufficient for most research (Delbeq, 1975).

Assumptions and Limitations

There are assumptions and limitations inherent in this research design. Throughout literature it is common to find researchers that do not use qualitative study methodologies. Unlike quantitative methodologies, qualitative methodologies inherently do not have external validity, meaning that the results of the qualitative study cannot be generalized across person, place, setting or time. Instead, a qualitative study provides rich thick detail, enough that the reader can reach their own conclusion of credibility of the study. But as in the case of this research, when no data or theory exists, a qualitative research design is required for theory building and to obtain a better understanding of a problem. Furthermore, a limitation of a Delphi methodology is that it may not be sufficient to be a defining property for an uncertain question because the expert's cultural bias can lead to similar answers to some questions which in fact are poorly known; or there could be an instance where the experts legitimately do not know the answer (Dalkey, 1963).

IV. Results and Analysis

The sponsor for this study is the 735th Supply Chain Operations Group. No such previous study has been accomplished on this topic. Therefore the problem has been defined and this study attempted to create theory that could provide a springboard for follow on studies. Through collaboration with the research sponsor and faculty advisor the Delphi design was selected and Delphi respondent groups defined.

Selection of Delphi Panels

As mentioned in chapter 3 of this study, it is important to note that throughout the Delphi literature, the definition of Delphi subjects as it applies to who is chosen has remained ambiguous (Kaplan, 1971). Some would argue that there are three types of panelists that help create a successful mix of panelists. These are stakeholders, those who are or will be directly affected; and experts, those who have an applicable specialty or relevant experience; and facilitators, those who have skills in clarifying, organizing, synthesizing, or stimulating (Linstone, 2002). And yet another researcher stated Delphi panel members should have knowledge and experience with the issues under investigation, capacity and willingness to participate, have sufficient time to participate, and effective communication skills (Skulmoski, 2007).

To select the best Delphi panel group for the Senior Non-Commissioned Officers and Civilians at the operational Supply Chain levels as seen in Table 2, the researcher contacted the Supply Corp. functional managers at Air Combat Command and Air Force Global Strike Command to select Senior Non-Commissioned Officers and Civilians for the study. The assumption is that the Supply Corp. functional managers for their respective Major Commands will have a greater understanding of their subordinates backgrounds, experiences and ability to provide relevance to this study.

Table 2: Senior Non-Commissioned Officers and Civilians Delphi Panel

Initial Survey Sent to n=21			Round 1 Responses n=13 (61% response rate)			Round 2 Responses n=13 (47% response rate)		
Respondent 1	407 SCMS	Civilian	Respondent 1	407 SCMS	Civilian	Respondent 1	407 SCMS	Civilian
Respondent 2	MXG/CCC	CMSgt	Respondent 2	MXG/CCC	CMSgt	Respondent 2	MXG/CCC	CMSgt
Respondent 3	LRS/LGLO	SMSgt	Respondent 3	LRS/LGLO	SMSgt	Respondent 3	LRS/LGLO	SMSgt
Respondent 4	EMXG	SMSgt	Respondent 4	EMXG	SMSgt	Respondent 4	EMXG	SMSgt
Respondent 5	LRS/CEM	CMSgt	Respondent 5	LRS/CEM	CMSgt	Respondent 5	LRS/CEM	CMSgt
Respondent 6	LRS/CEM	CMSgt	Respondent 6	LRS/CEM	CMSgt	Respondent 6	LRS/CEM	CMSgt
Respondent 7	LRS/LGRM	CMSgt	Respondent 7	LRS/LGRM	CMSgt	Respondent 7	LRS/LGRM	CMSgt
Respondent 8	LRS/LGE	CMSgt	Respondent 8	LRS/LGE	CMSgt	Respondent 8	LRS/LGE	CMSgt
Respondent 9	LRS/LGRM	Civilian	Respondent 9	LRS/LGRM	Civilian	Respondent 9	LRS/LGRM	Civilian
Respondent 10	LRS/LGRM	SMSgt	Respondent 10	LRS/LGRM	SMSgt	Respondent 10	LRS/LGRM	SMSgt
Respondent 11	ELRS/LGRM	SMSgt	Respondent 11	ELRS/LGRM	SMSgt			
Respondent 12	LRS/LGRM	SMSgt	Respondent 12	LRS/LGRM	SMSgt			
Respondent 13	A4RM/AFCENT	CMSgt	Respondent 13	A4RM/AFCENT	CMSgt			
Respondent 14	SCOG/GWC	Civilian						
Respondent 15	SCOG/CEM	CMSgt						
Respondent 16	USAFE A4/A4RN	Civilian						
Respondent 17	MSG/CCC	CMSgt						
Respondent 18	LRS/LGRM	SMSgt						
Respondent 19	LRS/LGRM	SMSgt						
Respondent 20	USAFE A4RMS	SMSgt						
Respondent 21	ELRS/CEM	CMSgt						

To select the best Delphi panel group for the second Delphi group comprised of officers and civilian equivalents in the rank of Lieutenant Colonel to Colonel or GS-14 to GS-15 as seen in Appendix 2, the researcher relied on the 735th Supply Chain Operations Group Commander to select the most relevant Delphi panel members. Since this Delphi panel is comprised of senior officers and civilians it is appropriate for the 735th Supply Chain Operations Group Commander to select and initiate contact with the senior level panelists. For this Delphi panel group my sponsor, the 735th Supply Chain Operations

Group selected the Delphi panel group, independent of the researcher, and resulted in a sample size of n=71 respondents.

Round 1 Survey

As previously stated, this topic has never before been researched and consequently there is no reference start point in literature. The impetus for a round 1 survey in this thesis is a brainstorming session for all Delphi panel members since there is no literature to provide a pre-ordained list of variables to rank order. The round 1 survey can be seen at Table 3. The researcher did note through a literature review that each questionnaire should be pretested on individuals who have not been involved in the design (Linstone, 2002). The round 1 brainstorming questionnaire was pretested by three of the researcher's cohorts, and approved by a prior Air Force Institute of Technology faculty member familiar with the Delphi technique. Feedback from the pretest were minor but improved the quality of the round 1 survey. The survey method of transmission has been chosen to be through e-mail. E-mail tends to have higher response rates over post mail, promotes faster response times, and respondents seem more willing to reply to open-ended questions (Sheehan, 2011). The round 1 survey was sent to the Senior Non-Commissioned Officer Delphi panel by the researcher on 17 December 2012 with a deadline for responses by 5 Jan 2013. Only 2 responses were received by the deadline of 5 January. Without any discernible way to attribute this low response rate, the most plausible reason provided by a few of the respondents was the survey coincided with the Christmas and New Year's Holiday season. On 7 January 2013 a follow up e-mail was sent to the Senior Non-Commissioned officer Delphi panelists to remind them of the required responses. Three more responses were received by 11 Jan 2013 in response to the reminder e-mail. On 14 Jan 2014 the researcher called each of the remaining 16 Delphi panelists to remind them of the necessity of their valuable responses to this study. All members were contacted. The final and 13th response to the round one survey for the Senior Non-Commissioned Officer panel was received on 30 January. Round one resulted in a response rate of 61%, required multiple follow ups and took 44 days.

The round 1 survey for the Senior Officer and Civilian Delphi panel was sent by the sponsor, the 735th Supply Chain Operations Group Commander, on 19 January 2012 with a deadline for responses by 29 Jan 2013 as seen on Appendix B. 18 responses were received by the researcher prior to the 29 January suspense and two more responses received on 31 January for a response (n = 20) rate of 28%. The Senior Officer and Senior Civilian Delphi panel responses were timely compared with the Senior Non-Commissioned Officer panel but did suffer a very low response rate. No follow up e-mails or phone calls were required and no survey responses received after 31 January.

With both of the Delphi responses received the task of categorizing the open ended brainstorming responses into like categories and terminology occurred. The researcher and three cohorts independently reviewed the list of inputs from the Delphi round 1 survey. All three cohorts and the researcher unanimously decided on categories (called variables in this study) with little effort or collaboration as seen in Table 4. All variables were counted by the frequency or number of responses and additionally by the number of individuals who responded with each variable. Many Delphi respondents responded with the same variable explained in more than one way. Another important note is that 102 responses not seen in figure 5 were not categorized into variables. Essentially, all 102 responses were unique. This list in Table 3 set the list that will be used for the Round 2 survey. In particular, those variables highlighted in yellow will be the eight variables the Delphi panelists will be asked to rank order. Recall this study's purpose is to identify variables that can be used to better predict aircraft mission essential parts shortages (MICAP). The researcher and three cohorts' agree that Readiness Base Leveling (RBL) Stock Levels, Contract Management, Cannibalization Management, and More Robust Spares Kits are not variables that could provide any increase in predicting MICAPs. Instead, they are tied more to safety stock (Stock Levels, and Robust Kits), Robbing Peter to pay Paul (Cannibalization Management).

Table 3: Round 1 Survey Categorized Results

Variable	# responses	# Individuals
MTBF	12	10
Factor Historical Demand Data	9	7
Local Weather/ Env't Conditions	14	11
ERP/IT Solution	7	6
Training	9	6
RBL/Stock Levels	8	5
Collaborate	12	7
Aging Aircraft Data	5	5
Contract Management	8	4
Cannibilization Management	5	4
More Robust Kits	6	3
Sensing Technology	3	3
Benchstock	6	5
Base Repair Management	4	3
Robust Phase Inspections	1	1
Faster Requisitions	1	1
Compute levels more frequently	1	1
Better Test Stations	1	1
TCTO Management	2	1

Round 2 Survey

For the second round survey the researcher delivered the survey via e-mail directly to both Delphi panel groups on 5 March 2013 and asked them to rank order the variables as seen in Appendix C. The round 2 survey can be seen at Appendix C. The researcher received 11 of the responses from the Senior Officer respondents before 8 March 2012 and the remaining two responses by 21 March 2013. The researcher received 6 responses from the Senior Non-Commissioned Officer Delphi panel by 8 March 2013 and the remaining 4 responses by 22 March 2013. All of the rank ordered responses were calculated using Kendall's Coefficient of Concordance herein referred to as Kendall's W (Kendall, 1990). As seen using the methodology below Kendall's W for round 2 is W = .24 for Senior Officers Delphi respondent group and W = .41 for the Senior Non-Commissioned Officer Delphi respondent group. As seen in table 1 of chapter three a Kendall's W = .41 is a weak agreement and low confidence in the ranks. A Kendall's W = .24 is a very weak agreement and no confidence in the ranks. The methodology for calculation is as follows (Kendall, 1990):

Kendall's W for Senior Non-Commissioned Officer Respondent Group

$$m = respondents = 10$$

$$n = objects = 8$$

$$S = (38-45)^2 + (25-45)^2 + (75-45)^2 + (57-45)^2$$
$$+ (53-45)^2 + (43-45)^2 + (33-45)^2 + (36-45)^2 = 1786$$

$$W = \frac{12S}{m^2(n^3-n)}$$

$$W = \frac{12(1786)}{10^2(8^3-8)}$$

$$W = .43$$

Can also be calculated as:

$$m = respondents = 10$$
$$n = objects = 8$$
$$S = (38-45)^2 + (25-45)^2 + (75-45)^2 + (57-45)^2 +$$
$$(53-41)^2 + (43-41)^2 + (33-41)^2 + (36-41)^2 = 1786$$

$$\max S = (10-45)^2 + (20-45)^2 + (30-45)^2 + (40-45)^2$$
$$+(50-45)^2 + (60-45)^2 + (70-45)^2 + (80-45)^2 = 4200$$
$$W = \frac{S}{\max S}$$
$$W = \frac{1786}{4200}$$
$$W = .43$$

Using the methodology above the researcher attempted to see if there were any significant outliers that contributed to the low agreement as calculated above using Kendall's W. Using variation of the responses by each variable, Mean Time Between Failure (MTBF) had the greatest variance in response of 5.3. Removing MTBF outlier and recalculating Kendall's W led to a Kendall's W = .48. This shows weak agreement with low confidence in the ranks.

Removing MTBF and the next outlier of Collaboration, the variable with the next highest variance, Kendall's W is recalculated as W = .56. This shows moderate agreement with fair confidence in the ranks.

The removal of only individual respondent outliers, respondents 9 and 10 led to a recalculated Kendall's W of W = .49. This shows weak agreement with low confidence in the ranks.

Six of the respondents from the Senior Non-Commissioned Officer respondent group are Chief Master Sergeant (CMSgt) and Senior Master Sergeant's (SMSgt) from only Logistics Readiness Squadron's. In an attempt to see if this homogonous sub group had a significant agreement the Kendall's W was recalculated. This homogonous group resulted in a Kendall's W of W = .22. This shows very weak agreement with no confidence in the ranks.

Kendall's W for Senior Officer/Civilian Respondent Group

$$m = respondents = 13$$

$$n = objects = 8$$

$$S = (38-58.5)^2 + (53-58.5)^2 + (77-58.5)^2 + (60-58.5)^2$$
$$+(81-58.5)^2 + (66-58.5)^2 + (50-58.5)^2 + (43-58.5)^2 = 1670$$

$$W = \frac{12S}{m^2(n^3-n)}$$

$$W = \frac{12(1670)}{13^2(8^3-8)}$$

$$W = .24$$

Can also be calculated as:

$$m = respondents = 13$$
$$n = objects = 8$$
$$S = (38-58.5)^2 + (53-58.5)^2 + (77-58.5)^2 + (60-58.5)^2$$
$$+(81-58.5)^2 + (66-58.5)^2 + (50-58.5)^2 + (43-58.5)^2 = 1670$$

$$\max S = (13-58.5)^2 + (26-58.5)^2 + (39-58.5)^2 + (52-58.5)^2$$
$$+(65-58.5)^2 + (78-58.5)^2 + (91-58.5)^2 + (104-58.5)^2 = 7098$$
$$W = \frac{S}{\max S}$$
$$W = \frac{1670}{7098}$$
$$W = .24$$

Using the methodology above the researcher attempted to see if there were any significant outliers that contributed to the low agreement as calculated above using Kendall's W. Using variation of the responses by each variable, IT Solution with variance in responses of 6.6 and Historical Demand with response variance of 6.1 were identified as outliers. Removing these outliers and recalculating Kendall's W led to a Kendall's W = .46. This shows weak agreement with low confidence in the ranks.

The removal of only individual respondent outliers, respondents 7 and 8 led to a recalculated Kendall's W of W = .50. This shows moderate agreement with fair confidence in the ranks.

Four of the respondents from the Senior Officer respondent group are identified as A4 Staff members. Isolating these four homogonous respondents led to a Kendall's W of W

= .24. This shows very weak agreement with no confidence in the ranks for the A4 Staff member homogonous sub group.

Four of the respondents from the Senior Officer respondent group are identified as Maintenance Group Commanders. Isolating these four homogonous respondents led to a Kendall's W of W = .45. This shows weak agreement with low confidence in the ranks for the Maintenance Commander Homogonous sub group.

Four of the respondents from the Senior Officer respondent group are identified as Supply Chain Operations Group members. Isolating these four homogonous respondents led to a Kendall's W of W = .43. This shows weak agreement with low confidence in the ranks for the Supply Chain Operations Group homogonous sub group.

Round 3 Survey

After two or three rounds, participants may become fatigued, and that, after three rounds max, stability and consensus should have been reached (Sumsion, 1998). After discussing the low agreement of round 2 results, low participation and timeliness of responses with the sponsor, 735th Supply Chain Operations Group, the Delphi study was concluded. It is the consensus of the sponsor and the researcher that a third round would not provide any significant increases in agreement.

V. Conclusions and Recommendations

Discussion

The purpose of this study was an attempt to identify agreement of variables of two subject matter expert groupings that would afford the United States Air Forces supply chain management processes the ability to predict aircraft mission essential parts shortages (MICAPS) before they occur. This research was essentially a first step towards identifying variables and issues to be studied in further detail on future studies. Since there is no literature on any pre-ordained list of Department of Defense predictive variables from previous studies, this Delphi study was chosen to flesh out agreement between subject matter experts and provide a compass for future studies.

Conclusion

In conclusion, neither of the Delphi panels (1. Senior Non-Commissioned Officer and Civilian Panel, 2. Senior Officer and Senior Civilian Panel) were able to come to any level of agreement as seen in table 4 below.

Table 4: Results of Kendall's W Calculations

SNCO and Civilian Delphi Panel	Kendall's W	Agreement
All Respondents	W = .43	Weak Agreement
Remove Outlier Variable MTBF	W = .48	Weak Agreement
Remove Outlier Variables MTBF and Collaboration	W = .56	Moderate Agreement
Remove Outlier Respondents 9 and 10	W = .49	Weak Agreement
Test Agreement for CMSgt and SMSgt Homogonous Sub-Group	W = .22	Very Weak Agreement

Senior Officer and Senior Civilian Panel	Kendall's W	Agreement
All Respondents	W = .24	Very Weak Agreement
Remove Outliers Variables IT Solution and Historical Demand	W = .46	Weak Agreement
Remove Outlier Respondents 7 and 8	W = .50	Moderate Agreement
Test Agreement for A4 Staff Homogonous Sub-Group	W = .24	Very Weak Agreement
Test Agreement for Maintenance Commander Homogonous Sub-Group	W = .45	Weak Agreement
Test Agreement for Supply Chain Operations Group Homogonous Sub-Group	W = .43	Weak Agreement

Rather than agreement, this research resulted in disagreement. This disagreement could be the result of a lack of a standardized understanding from the identified expert Delphi panels. This lack of agreement could also be due to the fact that each of the panel members has different experiences and have unique assignments and training throughout their careers making each of their contributions to the study unique. Essentially, the Delphi panel members were unable to agree on what the important variables are. This disagreement can be further supported by comparing Appendix 5 round 1 brainstorming response variables with the variances in responses to those variables in round 2. In particular, Mean Time Between Failure had the highest frequency and number of individual round 1 responses from the Delphi panel experts. However, Mean Time Between Failure was the outlier with the greatest variance in responses during the round 2 survey in the Senior Non-Commissioned Officer and Civilian Delphi panel. Additionally, round 1 responses resulted in the Historical Demand Data variable as a top three response by Delphi panelists. However, Historical Demand Data was the outlier with the greatest variance in responses during the round 2 survey by the Senior Officer and Senior Civilian Delphi panel.

Recommendations for Future Research and Limitations

One of the major limitations of this study is time. This study involved the selection of subject matter experts from a broad category of similar military ranks within the Logistics and Maintenance career fields. The broad categorization was assumed to be sufficient for the study and achievable within the time allotted for a 12 month residency at the Air Force Institute of Technology. After the findings in this study it is the thought of the researcher that future Delphi panels should be selected with strict criteria and rigor. This effort will take a considerable amount of time and require a student residency of greater than 12 months. One option is that Delphi panelists should be selected with very similar backgrounds, education and career paths. For example, one Delphi panel could be comprised of senior officers with experience in similar weapons systems and commands and academic backgrounds. Another recommended Delphi panel could be senior officers who all have graduated from an in-residence graduate program in logistics and supply chain management from the Air Force Institute of Technology or other top tier academic institutions.

In this study it is the conclusion of the researcher that as a whole, senior officer, civilian, and Senior Non-Commissioned Officers have very different perceptions of the Air Force supply chain management requirements process as a whole. Another possibility for future research would be very large sample sizes. Having rather large sample sizes could result in regression to the mean and perhaps significant agreement. Once again, the process of gaining Institutional Review Board approval for large sample sizes is time prohibitive for a 12 month student residency and a limitation of this study.

Appendix A: Senior Non-Commissioned Officer and Civilian Round 1 Survey

-----Original Message-----
From: Pankoski, Jeremy L Maj USAF AETC AFIT/ENS
Sent: Monday, December 17, 2012 2:01 PM
Subject: AFIT SCM Survey Sponsored by 735th SCOG

Supply Chain Leaders,

As a top tier subject matter expert in your career field, you have been hand-selected to participate in an Air Force Institute of Technology administered, Supply Chain Operations Wing sponsored research project. Congratulations! You're contribution in this research has incredible potential for large scale monetary and manpower savings.

The current Air Force enterprise Supply Chain system does a relatively good job getting parts in our artisan's hands. However, the Air Force still operates in a reactive environment for many mission essential (MICAP) parts. We've proven to be unsuccessful in predicting many MICAP parts needs for weapons systems across our enterprise, creating financial and manpower burdens across the wholesale and retail supply chains. The intent of this research is to identify variables/factors through a Delphi Study that can be used to predict future MICAP situations. The Delphi method originated in a series of studies that the RAND Corporation conducted in the 1950s. The objective was to develop a technique to obtain the most reliable consensus of a group of experts. All Subject Matter Experts (SME) responses will be anonymous to the other SME's in this study.

This is the first round (of three) surveys you will participate in for this research. You will be pleasantly surprised that the surveys are designed as to not take up too much of your already limited time. What's more, the time spent on these surveys is greatly appreciated and has a huge potential payoff for the Air Force.

SURVEY:

This first survey asks each SME to brainstorm and list eight or more factors you perceive as important (not in any order) that could be used to help predict MICAPs before they occur.

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Please send all of your responses to Maj Jeremy Pankoski (jeremy.pankoski@afit.edu) by 5 Jan 2013.

Appendix B: Senior Officer and Senior Civilian Round 1 Survey

-----Original Message-----
From: XXXXXXXXX Col USAF AFMC 735 SCOG/CC
Sent: Saturday, January 19, 2013 5:26 PM
Cc: Pankoski, Jeremy L Maj USAF AETC AFIT/ENS
Subject: AFIT Supply Chain Management Survey Sponsored by 735th SCOG

Sir/Ma'am,

The 735th SCOG is sponsoring a project by one of our AFIT students, Maj Jeremy Pankoski. A brief summary of the project is provided below, but he needs our help to complete his research. If at all possible, I respectfully request you share your perspective by completing the brief survey below. Yes, there will be a couple additional surveys in the future, but they will be short and your insight will be extremely valuable in helping us improve our supply chain.

Please send your responses to Maj Jeremy Pankoski (jeremy.pankoski@afit.edu) by 29 Jan 2013. Thanks in advance for your assistance.

Respectfully,

XXXXXXXXX, Colonel, USAF
Commander, 735th Supply Chain Operations Group
Joint Base Langley-Eustis, VA

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Supply Chain Leaders,

As a top tier subject matter expert in your career field, you have been selected to participate in an Air Force Institute of Technology administered, Supply Chain Operations Wing sponsored research project. Congratulations! You're contribution in this research has incredible potential for large scale monetary and manpower savings.

The current Air Force enterprise Supply Chain system does a relatively good job getting parts in our artisan's hands. However, the Air Force still operates in a reactive environment for many mission essential (MICAP) parts. We've proven to be unsuccessful in predicting many MICAP parts needs for weapons systems across our enterprise, creating financial and manpower burdens across the wholesale and retail supply chains. The intent of this research is to identify variables/factors through a Delphi Study that can be used to predict future MICAP situations. The Delphi method originated in a series of studies that the RAND Corporation conducted in the 1950s. The objective was to develop a technique to obtain the most reliable consensus of a group of experts. All Subject Matter Experts (SME) responses will be anonymous to the other SME's in this study.

This is the first round (of three) surveys you will participate in for this research. You will be pleasantly surprised that the surveys are designed as to not take up too much of your already limited time. What's more, the time spent on these surveys is greatly appreciated and has a huge potential payoff for the Air Force.

<u>**SURVEY:**</u>

This first survey asks each SME to brainstorm and list eight or more factors you perceive as important (not in any order) that could be used to help predict MICAPs before they occur.

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Appendix C: Delphi Panel Round 2 Survey

-----Original Message-----
From: Pankoski, Jeremy L Maj USAF AETC AFIT/ENS
Sent: Tuesday, March 05, 2013 12:15 PM
Subject: 735 SCOG and AFIT Round 2 Survey - Predicting MICAPs

Sir, Ma'am,

On behalf of the 735th Supply Chain Operations Group and the Air Force Institute of Technology, we respectfully request your participation in our round 2 survey below.

First and foremost we would like to thank you for your recent inputs on the initial round 1 survey. All of your responses have been categorized by a group of academicians and Air Force Logisticians. The list below represents the highest frequency responses from the first survey (in no particular order).

Survey Round 2 instructions:

Please reference the list of categorized responses below. Using your best judgment, rank order the items "1 - 8" where "1" represents the item on the list you believe could increase our ability to predict future MICAPs the most and "8" represents the item on the list least likely to help predict future MICAPs.

Please **do not consider how difficult or costly each of the items on the list would be to accomplish. Only consider the ability to help predict MICAP events.

____ Place greater emphasis on Mean Time Between Failure (MTBF) data

____ Place greater emphasis on historical demand data

____ Create a methodology to factor local weather and environmental conditions (effect on Failure rates)

____ Development of an Air Force Enterprise Resource Planning system (IT Solution)

____ Increase Airmen and Civilian training and education on the requirements process

____ Increased Collaboration between supply chain partners at retail and wholesale levels

____ Place greater emphasis on factoring Aging Aircraft variables into current methodology

____ Sensing Technology (technologies that predict failure in operating systems, monitor stockage levels in consumables, automatically report impending failures like in the Future F-35)

Appendix D: Senior Officer and Senior Civilian Delphi Panel

Initial Survey Sent to n=71			Round 1 Responses n=20 (28% response rate)			Round 2 Responses n=13 (18% response rate)		
Respondent 1	A4R/ AFGLSC	Colonel	Respondent 1	A4R/ AFGLSC	Colonel	Respondent 1	A4R/ AFGLSC	Colonel
Respondent 2	EMXG CC	Colonel	Respondent 2	EMXG CC	Colonel	Respondent 2	EMXG CC	Colonel
Respondent 3	A4R-3 ACC	Colonel	Respondent 3	A4R-3 ACC	Colonel	Respondent 3	A4R-3 ACC	Colonel
Respondent 4	SCOC CC	Lt Colonel	Respondent 4	SCOC CC	Lt Colonel	Respondent 4	SCOC CC	Lt Colonel
Respondent 5	SCOS CC	Lt Colonel	Respondent 5	SCOS CC	Lt Colonel	Respondent 5	SCOS CC	Lt Colonel
Respondent 6	SCOS DD	Civilian	Respondent 6	SCOS DD	Civilian	Respondent 6	SCOS DD	Civilian
Respondent 7	A4RM ACC	Civilian	Respondent 7	A4RM ACC	Civilian	Respondent 7	A4RM ACC	Civilian
Respondent 8	DLA	Colonel	Respondent 8	DLA	Colonel	Respondent 8	DLA	Colonel
Respondent 9	A4R AMC	Civilian	Respondent 9	A4R AMC	Civilian	Respondent 9	A4R AMC	Civilian
Respondent 10	MXG CC	Colonel	Respondent 10	MXG CC	Colonel	Respondent 10	MXG CC	Colonel
Respondent 11	A4R PACAF	Colonel	Respondent 11	A4R PACAF	Colonel	Respondent 11	A4R PACAF	Colonel
Respondent 12	EAMXS CC	Lt Colonel	Respondent 12	EAMXS CC	Lt Colonel	Respondent 12	EAMXS CC	Lt Colonel
Respondent 13	SCOG CC	Colonel	Respondent 13	SCOG CC	Colonel	Respondent 13	SCOG CC	Colonel
Respondent 14	A4R AFSOC	Colonel	Respondent 14	A4R AFSOC	Colonel			
Respondent 15	AF/A4LF	Lt Colonel	Respondent 15	AF/A4LF	Lt Colonel			
Respondent 16	A4-2/ ACC	Civilian	Respondent 16	A4-2/ ACC	Civilian			
Respondent 17	SMSM/GUMA	Civilian	Respondent 17	SMSM/GUMA	Civilian			
Respondent 18	A4/ AFCENT	Colonel	Respondent 18	A4/ AFCENT	Colonel			
Respondent 19	A4R/ USAFE	Civilian	Respondent 19	A4R/ USAFE	Civilian			
Respondent 20	AFSPC A4/7	Colonel	Respondent 20	AFSPC A4/7	Colonel			
Respondent 21	AFMC A4	Colonel						
Respondent 22	SCOS/DD	Civilian						
Respondent 23	SCMW/DV	Colonel						
Respondent 24	SCMS/CR	Colonel						
Respondent 25	AFGSC A5/8	Civilian						
Respondent 26	ACC A4R	Colonel						
Respondent 27	ACC A4R-2	Civilian						
Respondent 28	ACC A4R-3	Colonel						
Respondent 29	SCMG/CC	Colonel						
Respondent 30	MXG/CC	Colonel						
Respondent 31	SCOW/CC	Colonel						
Respondent 32	SCOW/LO	Colonel						
Respondent 33	SCOW/DV	Civilian						
Respondent 34	AF/A4LF	Colonel						
Respondent 35	AF/A4LX	Colonel						
Respondent 36	AF/A4LE	Colonel						
Respondent 37	ACC/A4-2	Civilian						
Respondent 38	ACC/A4-3	Colonel						
Respondent 39	SCOG/DD	Civilian						
Respondent 40	MXG/CC	Colonel						
Respondent 41	DLA	Colonel						
Respondent 42	MXG/CC	Colonel						
Respondent 43	AFCENT A4	Colonel						
Respondent 44	ACC A4-3	Colonel						
Respondent 45	USAFE A4/7D	Colonel						
Respondent 46	LRS/CC	Lt Colonel						
Respondent 47	LRS/CC	Lt Colonel						
Respondent 48	LRS/CC	Lt Colonel						
Respondent 49	EMSG/CC	Colonel						
Respondent 50	EMXG/CC	Colonel						
Respondent 51	ELRS/CC	Lt Colonel						
Respondent 52	EMSG/CC	Colonel						
Respondent 53	USAFE A4R	Colonel						
Respondent 54	AFMC AFSC/LG	Colonel						
Respondent 55	AFMC AFSC/CV	Colonel						
Respondent 56	EMXG/CC	Colonel						
Respondent 57	AETC A4/7D	Colonel						
Respondent 58	MXG/CC	Colonel						
Respondent 59	AETC A4R	GS-14						
Respondent 60	AFSOC A41	Civilian						
Respondent 61	AFGSC A4/7	SES Civilian						
Respondent 62	AFRC A4D	Colonel						
Respondent 63	ACC A4-2	SES Civilian						
Respondent 64	AFMC A4-R	Civilian						
Respondent 65	AFSPC A4/7	Civilian						
Respondent 66	PACAF A4-D	Civilian						
Respondent 67	AFGSC A4/7	Colonel						
Respondent 68	AFRC A4R	Colonel						
Respondent 69	AMC A4R	Colonel						
Respondent 70	AMC A4R Deputy	Colonel						
Respondent 71	AFMC AFSC/DS	Civilian						

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Vita

Major Jeremy Pankoski graduated from Horizon High School in Thornton, Colorado. He enlisted in the Colorado Air National Guard in 1993 and was an Electronics Warfare Systems Specialist at Buckley Air National Guard Base, Colorado. In 1999, he earned his Bachelor of Science in Biology from the Metropolitan State College of Denver, Colorado. In 2001, he was commissioned into the United States Active Duty Air Force as a Second Lieutenant earning Distinguished Graduate from Technical Training School. His first duty assignment was at Holloman AFB, New Mexico, where he earned a Master's of Science Degree in Human Resources Management from Troy State University. He is an Acquisition Professional who is Level II Life Cycle Logistics certified and has experience in retail and wholesale supply chain management. In May 2012, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned as the Commander, 78th Logistics Readiness Squadron, Robins Air Force Base, Georgia.

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14. ABSTRACT
Since the inception of the United States Air Force in 1947 it has cycled through many supply chain management organizational structures. Additionally, in the early 1950's the Air Force developed a major supply chain management data exchange operating system. As a result, the current Air Force enterprise supply chain system does a relatively good job getting mission essential aircraft parts into their artisan's hands most of the time. But despite their best efforts, the Air Force has proven to be unsuccessful in predicting mission essential parts needs at times for weapons systems across their enterprise, creating financial and manpower burdens across the wholesale and retail supply chain levels of operation.

This research is essentially a first step towards identifying variables to be studied in further detail. Since there is no literature or any pre-ordained list of Department of Defense predictive variables from previous studies, this Delphi study was chosen to flesh out agreement between subject matter experts and provide a compass for future studies.

The researcher found that neither of the Delphi panels was able to come to any level of agreement. The researcher provides limitations and recommendations for future research.

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MICAP, predictive variables, Kendall's W, Kendall's Coefficient of Concordance, Delphi, Air Force Supply Chain Management

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