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DEPARTMENT OF SUPPLY CHAIN AND INFORMATION SYSTEMS

USAGE OF ACCURATE FORECASTS FOR THE DEMAND OF CONSUMABLE SUPPLIES AND REPAIR PARTS FOR THE UNITED STATES DEPARTMENT OF DEFENSE

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Abstract

This paper investigates the potential usage of 100 percent accurate forecasts for the United States Department of Defense and the United States federal government agencies in order to determine which entities within the supply chain would use them and for what purpose. The research concentrates on consumable supplies and repair parts for Lockheed Martin's end items. An emphasis is placed on parts found in finished products used by the United States Marine Corps, particularly the Joint Light Tactical Vehicle. The topic of forecast accuracy is important because there is currently a tremendous amount of data available on Defense supply chain details. If it were possible to collect and leverage all of this information and accurately forecast the demand of materials, the United States Department of Defense and United States federal government agencies could gain greater efficiencies which would directly benefit the Warfighters. Information currently unavailable that could be useful to various Defense entities within the supply chain is identified through this research as well.

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Section 1: INTRODUCTION

Unlike companies in other industries, the United States military must abide by various rules and regulations that greatly complicate forecasting. To start, Congressional approval is required for any branch of the military to acquire an additional vehicle or other large finished good. Because Congress must approve, there are very few requests per year, and a forecast is not always pertinent (Feyedelem, 2010). Another complication arises due to the fact that the branches of the military cannot order consumable supplies or repair parts until the previous materials are used up or no longer at the goal-readiness rate required. It is only at this point that these goods can be ordered to avoid stockpiling at lower levels (Feyedelem, 2010). In theory, if forecasts were 100 percent accurate, the military would not require safety stock and would be able to order parts beforehand to have them exactly when they are needed.

Since forecasts for large finished goods are not always relevant, this research focuses on consumable supplies and repair parts needed for Lockheed Martin's end products. Lockheed Martin is the United States Government's biggest supplier of Information Technology (IT) services, systems integration, and training (Lockheed Martin Corporation [LM], 2010a). As such, the company produces many vehicles and weapon systems that are vital to the military's success. The research conducted for this paper follows consumables and repair parts needed for Lockheed Martin's Joint Light Tactical Vehicle (JLTV) through the supply chain. The JLTV is a companion trailer used by the Marine Corps and the Army that can execute a wide range of missions while providing protection and flexibility to Warfighters in many different types of terrain (LM, 2010b). Information about these parts has been collected at all supply chain touch points.

One hundred percent forecast accuracy is assumed in this research. This type of accuracy can lead to many benefits throughout the supply chain. Theoretically, no safety stock would be needed, and overall supply chain efficiency would increase as well. In addition, 100 percent accuracy should lead to decreases in obsolescence risks and transportation, holding, and handling costs. This research will examine both the quantitative and qualitative benefits of 100 percent forecast accuracy for consumables and repair parts for the JLTV, and it will ultimately identify which supply chain entities would benefit the most from this accuracy and in what ways.

Section 2: LITERATURE REVIEW

This literature review concentrates on academic research already conducted regarding the use and accuracy of common forecasting tools and methods. After an overview of general academic techniques, an emphasis is placed specifically on frequently used forecasting methods for consumable supplies and repair parts that can be applied to components needed by the United States military and government agencies. These forecasting methods tend to focus on products with intermittent demand, a type of demand that is prevalent in consumables and repair parts. This review will then provide evaluation criteria for all tools and techniques mentioned, followed by an explanation of how the forecast data can be used.

2.1: Forecasting Techniques

There are many different tools and methods available to create forecasts for the demand of goods. The demand for raw materials and other components, which is referred to as dependent demand, is determined by the demand for the finished product, known as independent demand. For this reason, the majority of forecasting methods tend to concentrate on independent demand items. Five traditional forecasting techniques that focus on independent demand and that are taught in an academic setting include the Simple Moving Average, Weighted Moving Average, Exponential Smoothing, Adjusted Exponential Smoothing for Trend, and Seasonal Influences. These popular methods have been pulled directly from material in a Supply Chain Demand Fulfillment course taught at the Pennsylvania State University by Dr. Robert Novack (Novack, 2008).

The Simple Moving Average is a basic technique that averages the demands for a certain number of periods in the past. An equal weight is assigned to each period. This method is simple to calculate but does not take seasons or trends into consideration and focuses only on recent data. The Simple Moving Average is calculated by the equation below (Novack, 2008).

A_t = Sum of last n demands/n = $D_t + D_{t-1} + D_{t-2} + \ldots D_{t-n+1}$

where

A_t = Average for period t

D_t = Actual demand in period t

n = Total number of periods in the average

The Weighted Moving Average gives each period in the past a certain weight, with more recent periods receiving a higher weight. All weights must ultimately add up to one. While this method is generally considered better than the Simple Moving Average, it too has shortcomings. Assigning weights, determining how many periods to use, and taking seasons into consideration prove problematic. The formula below is used for a Weighted Moving Average with three previous periods (Novack, 2008).

$A_t = W_1D_t + W_2D_{t-1} + W_3D_{t-2}$

where

A_t = Average for period t

D_t = Actual demand in period t

W_1 = Weight for most recent period

W_2 = Weight for second most recent period

W_3 = Weight for third most recent period

Exponential Smoothing is calculated using a smoothing constant between zero and one, the most recent demand, and the average of previous demand. The higher the constant, the more weight placed on recent demand. It is difficult to set the smoothing constant, and the forecasts sometimes lag demand. Like the Simple Moving Average and Weighted Moving Average, seasons and trends are not considered. The formula can be found below (Novack, 2008).

A_t = α(Demand this period) + (1 - α)(Forecast calculated last period)

$= \alpha D_t + (1 - \alpha)A_{t-1}$

where

A_t = Average for period *t*

D_t = Actual demand in period *t*

α = Smoothing constant

The Adjusted Exponential Smoothing for Trend, as the name implies, takes trends into consideration. Two constants are used for this method, both of which are between zero and one. An additional equation is used for the trend. Both are found below (Novack, 2008).

A_t = α(Demand this period) + (1 - α)(Average + Trend estimate last period)

$= \alpha D_t + (1 - \alpha)(A_{t-1} + T_{t-1})$

T_t = β(Average this period – Average last period) + (1 – β)(Trend estimate last period)

$= \beta(A_t - A_{t-1}) + (1 - \beta)T_{t-1}$

where

A_t = Exponentially smoothed average of the series in period *t*

T_t = Exponentially smoothed average of the trend in period *t*

α = Smoothing parameter for the average

β = Smoothing parameter for the trend

To calculate Seasonal Influences, the four-step process listed below must be followed. Identifying the various seasons is the challenge with this method (Novack, 2008).

1. Average demand for each season in every year is calculated.
2. Divide demand for a season by the average demand per season for that year.
3. Calculate an average seasonal index for all of the years.
4. Multiply each season by its seasonal index to get an estimate of the average demand per season for the next period.

In addition to these five broad forecasting methods, there are several techniques used specifically for consumable and repair parts. Other students and academics have already conducted research and gathered data on forecasts for consumable and repair parts used in various military settings. The next section of this review will summarize the findings of two such researchers. John M. Surma conducted research on forecasting methods in the maintenance, repair, and overhaul (MRO) industry, focusing specifically on the aerospace market and Lockheed Martin’s customers (Surma, 2010). Andrew Howard Charles Eaves wrote a thesis on forecasting methods for consumable parts used by the Royal Air Force (RAF) (Eaves, 2002). The methods that they studied are described in detail below.

Surma first analyzed the following three academic forecasting methods: Auto Regressive Integrated Moving Averaging (ARIMA)/Box Jenkins Approach, Croston’s Method, and Bootstrapping (Surma, 2010). Shifts and lags in the ARIMA Time Series Analysis are used to discover seasonal patterns and trends in data which then help determine future demand (Pankratz & Woolbridge, 2010). The Croston Method uses a model that combines exponential smoothing and average time between the demands (SAP Supply Chain Management [SAP SCM], 2006). Bootstrapping involves creating a probability distribution by resampling data from information that has already been gathered (Teknomo, 2006).

Commercial methods and tools were then analyzed by Surma. Two leading forecasting packages for products with intermittent demand include SAS Demand-Driven Forecasting and SmartForecasts. SAS Demand-Driven Forecasting consists of several time series methods and is used with sales and operations planning (S&OP) to improve forecast accuracy and reduce inventory levels (SAS Institute, 2010). Companies that use a package from SmartForecasts achieve high forecast accuracy in demand as the package creates tens of thousands of future demand scenarios through the bootstrapping technique (Smart Software, 2010).

Surma also analyzed several commercial tools that are used specifically for MRO forecasting. First, Thomas Group MRO Management can decrease a company's costs by 15 to 35 percent by identifying and managing cost drivers related to MRO (Thomas Group, 2010). AeroStrategy and OAG (Official Airline Guide) Aviation have been working together since 2008 to create MRO forecast databases for aviation companies (AeroStrategy, 2010). Enigma 3C (content, commerce, and collaboration) includes a Military Maintenance IETM (Interactive Electronic Technical Manual) Application designed to support soldiers on the field with maintenance information (Enigma, 2010). Maximo Asset Management offers software that provides maintenance management and increases part availability (IBM, 2010). Miro Technologies customizes software solutions for the aerospace and defense industries to cut costs and create efficiencies in logistics (Miro Technologies, 2010). Radio Frequency Identification (RFID) technology could also prove valuable to MRO forecasting for the military in the future (Surma, 2010).

Like Surma, Eaves also analyzed Croston's Method in his research. He then evaluated additional methods, including a Revised Croston's Method, Bias Reduction Method, and Approximation Method. A major issue with Croston's Method is the bias that results from using demand estimates that have been updated during times of positive demand. The three techniques that Eaves further examined try to remove this bias from the forecasts to increase overall accuracy. The demand size is updated for the Revised Croston's Method, and a deflator is used in the Bias Reduction and Approximation Methods to account for the bias. Forecast accuracy is essential to the RAF to ensure that operational capacity has been maximized (Eaves, 2002).

2.2: Forecast Error

While some methods prove more accurate than others, no forecast is ever 100 percent accurate. There are various formulas that can be used to determine the accuracy of the forecasting techniques and methods previously described. This section will outline several of the most commonly used measures. First, the cumulative sum of forecast errors (CFE), also known as bias, incorporates positive and negative errors to provide an overall forecast error. Second, the mean squared error (MSE) ensures that positive and negative errors do not cancel each other out by squaring the error for each period. While the CFE often produces an error total that is too low, the MSE is usually fairly accurate (Novack, 2008).

Third, the mean absolute deviation (MAD) eliminates positive and negative signs by using each error's absolute value (Novack, 2008). MAD+ is sometimes used to indicate forecast errors that are more than five percent greater than the true value, while MAD- can signify errors more than five percent less than this value (Eaves, 2002). Fourth, the Root Mean Square Error (RMSE) calculates how much deviation occurs between the actual and forecasted values to determine accuracy (Surma, 2010). Finally, the Mean Absolute Percentage Error (MAPE) divides the absolute value of the error by the sum of the actual demand values, which allows for the comparison of various kinds of forecasts (Novack, 2008). Unlike MAPE, the Median

Absolute Percent Error (MdAPE) removes high and low outlying errors to decrease bias (Armstrong & Collopy, 1992).

Other evaluation criteria that can be used to determine forecast accuracy include the Akaike Information Criterion (AIC), Adjusted R-Square, Normality Error, Cochrane-Orcutt Estimation, Theil's Statistic, Forecast Cost, Forecast Horizon, and Safety Stock (Surma, 2010). Formulas for the CFE, MSE, MAD, RMSE, and MAPE can be found below in Table 1.

Table 1: Common Formulas for Forecasting Errors

Cumulative Forecasting Error	CFE	$CFE = \sum \boldsymbol{Et}$
Mean Square Error	MSE	$MSE = \frac{\sum Et}{n}$
Mean Absolute Deviation	MAD	$MAD = \frac{\sum_{t=1}^{n} \lvert Dt - Ft \rvert}{n}$
Root Mean Squared Errors	RMSE	$RMSE = ((\sum(F_t - A_{t)})^2)/n)^{1/2}$
Mean Absolute Percentage Error	MAPE	$MAPE = \frac{(100\sum \lvert Et \rvert / At)}{n}$

where

A_t = Average for period t

D_t = Actual demand in period t

E_t = Forecast error = Absolute value of D_t - F_t

F_t = Forecast for the upcoming period

n = Total number of period in the average

2.3: Forecast Applications

After a forecast method has been selected and data has been gathered, the information can be used by companies in various ways to improve their supply chains. Many industries now choose to use the data for Sales & Operations Planning (S&OP) and Collaborative Planning, Forecasting, and Replenishment (CPFR), two initiatives that have become very popular in recent years. Other initiatives that are sometimes used include Quick Response (QR), Vendor-Managed Inventory (VMI), Continuous Replenishment Planning (CRP), and Efficient Consumer Response (ECR) (Novack, 2008).

The S&OP process starts with a company's sales forecast and moves through five steps, ultimately creating one internal forecast that the sales, operations, and finance business functions can all agree to implement (Novack, 2008). SAS Demand-Driven Forecasting, for example, is used along with S&OP to improve forecast accuracy and reduce inventory levels (SAS Institute, 2010). While S&OP is used among internal business units, CPFR is a popular initiative that creates one forecast for all entities in a supply chain. Retailers, distributors, and manufacturers all work together and share information to reach a single forecast. When this single forecast is executed, inventories and out-of-stocks are often greatly reduced (Novack, 2008).

There are several other initiatives that have been used to integrate supply chain processes in an attempt to improve forecast accuracy, increase service, and reduce costs (Sheffi, 2002). First, QR aims to decrease order response time to consumer demand by encouraging partnerships among external business members. Second, VMI allows the vendor to have access to data on sales and inventory levels, meaning the manufacturer can be responsible for controlling inventory levels. Third, CRP involves managing various sources of information for every new relationship that is created between business partners. Finally, ECR concentrates on enhancing consumer service and maintaining low inventory levels through improved promotions, products, and store assortment (Sheffi, 2002). A major shortcoming of these particular processes as opposed to CPFR is the lack of incentive for collaboration between all entities in the supply chain (Novack, 2008).

A considerable amount of research has been conducted regarding the various kinds of forecasting methods and the evaluation criteria used to determine their accuracy. Conversely, little research has been conducted concerning the benefits that could be gained from 100 percent accuracy. Forecast accuracy is vital to all companies, arguably even more so for the military and government agencies due to the high risks of stock-outs. The success, and oftentimes safety, of Warfighters is directly related to their ability to obtain equipment and other products when needed. This paper will therefore follow consumable supplies and repair parts for a Lockheed Martin product, the Joint Light Tactical Vehicle (JLTV), through the supply chain to gain valuable information about the effects of 100 percent forecast accuracy.

Section 3: RESEARCH METHODOLOGY

The data used for this research was all primary data, both qualitative and quantitative, and was obtained from various stakeholders at different entities within Lockheed Martin's supply chain. Interviews were conducted with contacts at the following touch points:

- Reliability & Maintainability Engineering – Lockheed Martin
- Subcontractor – Lockheed Martin
- Management Body – Defense Logistics Agency
- Transportation Network – FedEx
- United States Armed Forces – Marine Corps
- Depot – Marine Corps Maintenance Center Albany
- Point of Need – Marine Corps Warfighter

Please reference the Appendix for the Interview Questions Template that was used in all interviews with the stakeholders listed above.

The interview topics and questions were approved by several professionals before conducting interviews. These professionals include Dr. Robert Novack, Associate Professor of Supply Chain Management at the Pennsylvania State University, and Dr. Carlos Amaro, Project Engineer at Lockheed Martin. A pre-test was conducted with Lieutenant Colonel Christopher Feyedelem for additional feedback on the questions.

Data for this study was collected mainly from September 2010 through March 2011. Specific timing for all data collection depended mainly on the availability and schedules of the contacts that were interviewed. When permission was granted by the stakeholder, responses to all questions were taped with a sound recorder during each interview to assist with data analysis. To add to the credibility of the information gathered, all contacts were determined by professionals at both the Pennsylvania State University Center for Supply Chain Research and Lockheed Martin.

Primary data collected through interviews was most appropriate for this kind of study because there is already an abundant amount of research on various forecasting techniques and methods. Valuable information was gained by contacting the people who work directly with the consumable supplies and repair parts as they move along the supply chain. These stakeholders were able to share their years of experience, along with detailed examples, regarding how forecasts have been calculated and for what purpose.

Section 4: INTERVIEW RESULTS

4.1: Reliability & Maintainability Engineering – Lockheed Martin

Bil Allen, a Reliability & Maintainability Engineer at Lockheed Martin, participated in a phone interview on March 17, 2011. Allen has over 26 years of experience in this department, during which time he has worked closely with design engineers as part of an Integrated Product Team (IPT) to ensure that product designs are reliable and maintainable. While he has worked with all branches of the military, he has spent the last two years heavily focused on the Army and Marine Corps as part of the JLTV team. As a Reliability & Maintainability Engineer, Allen tests final products and systems. His team also works with suppliers to ensure that all components are of high quality. The following section summarizes the content discussed with Allen during the interview.

To perform Material Requirements Planning (MRP), Lockheed Martin uses SAP for all of its projects. Reliability data gathered from Allen's role is passed on to logistics employees who perform spares and repairs modeling with their tool, which also takes into consideration how many systems are running, how many hours those systems are running, and the entire operational scenario. From that data, they can forecast how many parts are needed to keep the pipeline full and the system running. Spares for consumables and repair parts are ordered through the SAP system to ensure that they will be in stock. If anything fails, a part can then be pulled out of stock to get the system back up and running. The part that failed would be sent to get repaired and added to the stock of spares once it was fixed.

Lockheed Martin takes various factors into account when calculating forecasts. The government provides the company with specifications on how products will be used and how much to keep in stock. For the JLTV program, for instance, the government has stated how many hours the products will be in stages such as idle, operational, silent watch, and maneuver. Other programs can also receive information regarding if the products will be used for training versus war time. Lockheed Martin uses all of these specifications from the government in its SAP tool to help forecast for spares and repair parts.

The company's ability to determine the accuracy of forecasts depends on program length. The JLTV program is currently in test phase, and only ten prototypes have been delivered. Forecasts have been calculated but only for the one year test period and not for the entire life of the vehicle. Adjustments must be made based on reality; the JLTV program has not gotten to the point where the company can validate whether primary forecasts were accurate or not. There are also programs where hardware or a computer box is built and delivered, but no feedback is ever received. Programs that have been around for several years, such as Lockheed Martin's helicopter program, can better be assessed for forecast accuracy. For the helicopter program, an initial forecast was created and then adjusted over the years as actual data was compiled and feedback received from the government.

Whether program length is long or short, accuracy will always vary to a certain extent since forecasting is fundamentally a prediction. Many variables must be taken into account, and the tools that are used are not perfect. Also, the operational scenario that the government specifies can change over time. By the time the products are delivered and start being used, they could be needed for something completely different than for what they were originally forecasted. While there is a science to it, forecasting is still very difficult to do well. Better visibility and increased communication along the supply chain would be helpful to attain improvements, more so than the addition of any particular tool.

This upstream section of the supply chain would benefit immensely from 100 percent forecast accuracy. The first factor that would be affected is safety stock inventory. Safety stock generally varies depending on how much risk the company is willing to take. If it does not want to take any risks, money is spent to build safety stock levels to ensure that parts are available if needed. If a program is low on money, the company is usually willing to take some risks by keeping safety stock levels lower. The company will take a hit every once in a while when something fails and a spare part is not in stock. The system will have to sit idle until a new part arrives and can be used. With 100 percent forecast accuracy, safety stock would not be needed since the risk of stocking out would be eliminated.

Cycle stock, the second factor, is affected as well. Forecast accuracy would ensure that the correct amount of stock is always ordered. However, exceptions do exist for this factor. Many components that are bought must be purchased in minimum order quantities. For example, 100 piece parts may be needed, but the manufacturer will only sell them in boxes of 1,000. Most often, the extra 900 would eventually get scrapped. Sometimes extra parts can be used for other programs, although the government must provide approval since it is their money used to purchase the piece parts. Even if forecasts were 100 percent accurate, there is still a chance that the company would have to over-order because of minimum order quantities.

The third factor is product quality. All items that come from suppliers receive an official inspection, during which time the real quality of the parts is determined. During testing, parts sometimes fail because of poor quality and cannot be used. Even if the correct number of parts is shipped, shortages may result when parts fail the inspection. If Lockheed Martin knew that forecasts would be 100 percent accurate and that all parts would be of acceptable quality, these shortages would not occur.

Risk of obsolescence is the fourth factor. If there are extra parts left over at the end of a program in safety stock inventory, the parts will generally get scrapped. In addition to losing the money that was spent to purchase the parts, it also costs money to actually scrap the materials. The parts can sometimes be used for different programs and across agencies, but government permission must be obtained, which is very difficult. If 100 percent forecast accuracy was achieved, safety stock would not be needed. Extra parts would subsequently not become obsolete, and the government would save large amounts of money.

The fifth variable is cost of transportation. Deliveries often get delayed because of inaccurate forecasts. When this type of situation occurs, the company can make up for some of the time by using a faster and more expensive mode of transportation to ship the materials. If an item gets delayed, overnight transportation could make up some time instead of waiting for regular shipment of the product. The final factor, warehouse space, is also affected. The company's ideal situation is just-in-time (JIT), having just enough inventory at the right time. The more safety stock that is needed due to uncertainty, the more warehouse space needed to store it.

Overall, supply chain efficiency would significantly improve as forecast accuracy improves. With 100 percent forecast accuracy, there would be large financial impacts all along the supply chain. Ultimately, the Marines and other Warfighters would greatly benefit from all of these improvements.

4.2: Subcontractor – Lockheed Martin

Lockheed Martin Subcontract Program Manager Andrew Booker participated in a phone interview on January 21, 2011. He manages a team of 22 employees who report to him on all ground vehicle programs, the biggest of which is the JLTV Program. Within the JLTV Program, he has 11 team members who manage all of the vehicle's subcontracting activity, including commercial automotive components such as engines and brakes. He is responsible for the entire supply chain effort for the JLTV Program. The following section summarizes the content discussed with Booker during the interview.

When the government issues a new vehicle or weapons system, the item goes through three specific forecasting phases from a subcontracting point of view. The first phase is Technology and Development, which is the phase that the JLTV Program is in currently. The government purchases a small quantity of vehicles (11, for example). The subcontracting team then builds the vehicles and runs them through a series of tests to ensure that the platform performs as expected. The next phase is Engineering and Manufacturing Design. A higher quantity of vehicles (50, for example) is built during this phase. The objective is to take the technology that was developed in the first phase and mature it so that it is manufacturable before starting full production in the last phase.

The third and final phase is Production, where approximately 50,000 to 60,000 vehicles may be built for the government. To forecast this large amount, the government uses a quantity model. For example, over a production lot of three years, the government may request 1,000 per month of configuration x, 3,000 per month of configuration y, and 5,000 per month of configuration z. Using those given quantities, the subcontracting team determines how they will affect the buying perspective of the suppliers. The more the quantities change or the less accurate they are initially, the more the pricing changes with the production contract and the more flexible suppliers must be to adapt to those changes.

Stability in initial quantities would prove useful to the subcontracting team in regards to forecasting. Quantities for the JLTV Program have been very unstable, which is driven primarily by the fact that the government is uncertain how much funding will be put towards the program. This uncertainty causes the quantities to change over time. The government may order 20,000 vehicles in the first production lot but cannot provide details on how many of each different configuration should make up that total of 20,000.

If 100 percent forecast accuracy was achieved, this entity in the supply chain would gain significant benefits. First, accuracy would affect quantity estimations to suppliers, which would in turn affect the suppliers' pricing for parts. Quantity estimations would become firmer since the subcontractors would provide all suppliers with the exact quantities that will need to be produced per month for each configuration. Some suppliers only have parts on certain configurations. The government may request 20,000 vehicles total but only 3,000 of those 20,000 are configuration x. If a supplier only produces parts for configuration x but merely knows the total quantity of 20,000 vehicles, its pricing given to the subcontractors will be inaccurate. If the supplier knows initially that it will need to produce only 3,000 parts, pricing will be accurate.

Second, forecast accuracy will affect capacity planning for both suppliers and the subcontractors. Knowing the exact volumes that the customer will order over time facilitates suppliers' capacity planning for manufacturing parts. Many suppliers have other customers whose products run on the same assembly lines, and decision-making for the lines becomes much easier when exact quantities are known from the start.

Third, safety stock inventory will dramatically decrease with perfect forecasts. When the accuracy of demand is unstable, more safety inventory (also called strategic inventory by the subcontracting team) is needed to account for unexpected surges. If predictions were 100 percent correct, the amount of safety inventory needed to be kept on hand would be much smaller, which would save the company money.

The fourth factor, product quality, could also potentially improve. A quality process should always be in place that enables the production of an error-free product. However, when forecasting is inaccurate, issues may arise in the assembly process since tooling may have to be switched in and out of the line more frequently. For example, the technicians may plan to produce a full batch of one product across a given week to fulfill an initial quantity estimation. If that given quantity then increases or decreases because of inaccurate forecasting, changes have to be made to assembly forecasting and planning at the plant. Tooling may have to be moved around even though that was not previously expected. This unanticipated switching in tooling can negatively impact quality.

Fifth, work quality improves with accurate forecasts and can provide tremendous savings. Many people are involved in the planning process, including a scheduler who oversees planning out all of the tests that need to be completed to prepare for production. During production, all of the production planners and managers plan the workload across the assembly line. When the demand forecast changes, all of the work that the planners have already completed needs to be redone. Recreating production plans is not value-added work and takes up time that could be spent elsewhere.

Finally, from a subcontracting perspective, transportation costs would decrease and transportation efficiency increase with perfect forecast accuracy. If the exact amount of parts needed is known and can be planned for over a longer period of time, the company may be able to use full truckload shipments. If the quantities are constantly changing, half shipments or quarter shipments may have to be used, which is much less efficient and ultimately more costly.

While all business functions are affected by 100 percent forecast accuracy, supply chain planning and production planning departments in particular would be greatly affected. Whenever a change is made, it ripples from the leading production assembly plant down through the supply chain. For example, there are 96 suppliers working on the JLTV Program. If volumes change, the subcontractors must first notify the plants to adjust the production schedule. Significant planning is needed to make all of the changes and adjustments, which must then be communicated to all 96 suppliers. These suppliers have their own production lines that then need additional changes. The changes that occur during this process consequently impact all of the pricing that the subcontractors had provided to the customer since the pricing had been based on the original quantities.

4.3: Management Body – Defense Logistics Agency

A phone interview was conducted on March 7, 2011, with Michael T. Brletich of the Defense Logistics Agency (DLA). Brletich is currently the Deputy National Account Manager of the Marine Corps Team in the J-3/4 at DLA headquarters. In this role, he serves as the conduit between the Marine Corps and the DLA and is responsible for advising an active duty Marine Colonel on all matters concerning DLA support. Brletich is a retired Marine Corps Officer with 28 years of United States Marine Corps logistics experience. The following section summarizes the content discussed with him during the interview.

For the DLA, forecasting is the means by which its supply centers know what the Marine Corps requires so that the Marines can be supported properly. Knowing what the Warfighters need is crucial to ensuring that the DLA has the right products at the right place at the right time, especially overseas for the war efforts. If the DLA knows about the requirement, it is likely that it will be supported fully. If the DLA does not know what the Warfighters need, it is very difficult to support them well.

There are many different ways to calculate forecasts. The initial forecast is based on historical demand patterns from the DLA's Enterprise Resource Planning (ERP) system, which uses SAP software as a foundation. When any type of material is needed, whether it be a repair part or consumable, this ERP system records the demand pattern. This pattern is then the starting point for future forecasts, informing the DLA as to what it will need to buy in the future to support the Marine Corps.

Additional requirements always exist outside of the normal demand pattern. The DLA has several mechanisms used to deal with these occurrences. For example, a forum known as the Industrial Forecasting Support Group (IFSG) is held quarterly. During this forum, a combination of people from the DLA, Marine Corps, and Supply Centers meet and discuss requirements that happen outside of normal demand. Another example involves support overseas in Afghanistan and Iraq. The Marine Corps provides the DLA with an automated list of items believed to be needed for a certain effort, and the DLA in turn gives a Supply Center a list of requirements. The Supply Center then creates a supportability estimate on what the Marine Corps will need. When the Marine Corps starts submitting actual requisitions to the Supply Center, it is able to support the requirements.

Actual forecast accuracy depends on a variety of factors, and the quality of the forecasting depends on the quality of the input received to calculate the forecast. The investment strategies at the Supply Centers are based heavily on expected requirements. If a certain amount of money is set aside to buy stock, but the wrong type is purchased because of requirement changes, one of two situations will occur. First, the stock becomes dormant and sits on the shelf with no use. Second, the stock that was actually needed is not on shelf, and there is no more money left to buy the proper parts. The DLA clearly tries to avoid these types of situations.

There are two factors that would significantly improve forecast accuracy for the DLA. The first factor is communication up and down the supply chain. End to end collaboration and communication between the customer and all other supply chain entities is extremely important. Sometimes the DLA does not know about a requirement until the last minute simply because of a lack of communication among various parts of the supply chain. This collaboration is especially important for an organization as complex as the DLA, which manages 3.8 million separate line items (national stock numbers or NSNs). Its 25 Distribution Depots and three Supply Centers must be managed as well, all while currently supporting an active war in Afghanistan.

The second factor is funding, a constraint that is especially relevant in today's fiscal climate of budget cuts. Without the proper funding to do business, supply chain managers must make investment decisions as to what to put on the shelf. With unlimited funding, there would always be more money to purchase additional items if requirements change. Since funding will always be a limited factor, it is vital to have high forecast accuracy in order to make the right investment decisions to ensure that the needed products are put on shelf at the outset. The goal is to have a high inventory turnover ratio, and poor investment decisions will cause the ratio to decline rapidly. The company in turn losses money, which essentially comes from the United States taxpayers.

If 100 percent forecast accuracy was attainable, the DLA would benefit in many ways. First, safety stock and stock-outs would reduce as accuracy increases. The following example illustrates the need for forecast accuracy to reduce safety stock inventory. The DLA provides all of the uniforms for the Marines, Sailors, Soldiers, and Airmen going through training and boot camp. Approximately 30 to 60 days worth of inventory is currently held as safety stock at the training depots. Uncertainty currently exists not only in how many new recruits will come through the training depots but also in their clothing sizes. If the DLA knew the exact number of new recruits, along with their sizes, no safety stock inventory would be needed.

Second, work quality would improve with better forecast accuracy. While forecasting does not have a great impact on product quality due to high quality standards, the product's work quality could potentially be jeopardized if the industrial base is pushed to make more parts in a shorter period of time because of an inaccurate forecast. There are instances where overtime must take place because of an inaccurate forecast or due to a last minute requirement. A vendor may have to put in extra work in order to meet the deadline for the requirement, and the DLA may have to pay a premium for this overtime.

Cost of transportation is the third factor affected by accurate forecasts. While transportation costs generally remain fairly constant, last minute requirements could cause costs to increase. When the Marine Corps needs parts in Afghanistan, the DLA normally sends the parts via ship. This surface transportation takes roughly 30 to 45 days and is about 0.25 cents per pound. If a forecast is inaccurate and there is a last minute requirement, the parts may have to be shipped via premium air transportation to the war zone. Air transportation takes only a few days and costs approximately $2.50 per pound, ten times the cost of surface transportation. Transportation costs increase greatly to guarantee that the parts reach the Marine Corps in time.

Fourth, warehouse space and costs would be affected by forecast accuracy. Warehouse requirements and the amount of needed shelf space will not be accurate if forecasting is incorrect. More or less space may be needed depending on whether the forecast is too high or too low. If less space is actually needed, overhead costs are directly impacted. These expenses include the warehouse space, the light bill, the heater, the number of people working in the warehouse, among many others. Money is wasted when the entire warehouse is not being used.

Overall, forecasting is one of the most important parts of the supply chain. Generating accurate forecasts is critical to achieving efficiency along every section of the supply chain. Communication and collaboration must exist among all members involved in order to create accurate forecasts and avoid negative results such as those created by the bullwhip effect.

4.4: Transportation Network – FedEx

A phone interview was conducted with Kirstin Knott of FedEx Corporation on January 28, 2011. As the Managing Director of the Department of Defense (DoD) Sales Team, Knott negotiates with United States Transportation Command (USTRANSCOM) and has a team of eight worldwide account managers that works for each of the specific military services. She and her team are responsible for selling domestic, international, and ground services, and her worldwide responsibilities include Afghanistan, Iraq, and all other geographic coverages of the military. The following section summarizes the content discussed with Knott during the interview.

When a transportation provider such as FedEx sells services to the government, a three-step process is typically involved. First, the idea is sold to the policy makers, who then deal with the contracting officers for the solicitation as part of the second step. Finally, the individual bases or contractors work to have the package actually moved by the provider.

FedEx has engagement with Lockheed Martin in several ways. Raw materials from Lockheed Martin are generally sent by surface transportation instead of air due to their weight, value, and size. Unless the product is extremely valuable or there is concern of pilferage or damage in transit, it will most likely move by surface transportation. However, if the materials are needed immediately to keep a line running, they may be sent by air transportation. The shipper may either receive commercial pricing or be granted government pricing, meaning that

Lockheed Martin has several different rate structures with FedEx depending on the type of material being shipped. Some of Lockheed Martin's weapon platforms, such as the JLTV, may be eligible to receive government pricing based on whether or not they have cost reimbursable contracting with the government.

To generate forecasts, FedEx works with the shipping and transportation department of a Lockheed Martin location to gather basic information such as when the boxes will be ready to be picked up, how many boxes need to be shipped, and the average weight of the boxes. This information is necessary to determine when FedEx should arrive and how big of a truck FedEx will need to send out in order to either ship the boxes via surface transportation or deliver them to the airplane to be shipped by air.

Challenges for FedEx arise when Lockheed Martin experiences surges and does not immediately pass this information onto FedEx. If the change in quantity is fairly low (for example, a change in less than 100 boxes), FedEx may be able to accommodate it with the existing flexibility in its network. It is much more difficult for FedEx to react immediately when the quantity change is in the thousands or tens of thousands. In FedEx's air express industry, surges are typically seen at the end of every month, quarter, and fiscal year. Knowledge of this trend, along with a tremendous amount of operational research and historical examination, allows FedEx to plan accordingly.

The accuracy of current forecasts for FedEx tends to vary. FedEx Express generally hits approximately 70 to 80 percent accuracy in predicting forecasts. While the inaccuracy is often caused by customers underestimating or overestimating their demand, it could also be caused by less common issues such as recalls or manufacturing failures. If a certain type of equipment or a particular part is deemed no longer in working condition for one of those reasons, forecast accuracy would greatly decrease.

Improved communication from customer to transportation provider would assist with generating accurate forecasts. The transportation provider is not always the entity that comes to mind first when companies think about their forecasting, and details regarding surges and other changes in demand are consequently not always communicated immediately. While full integration with Lockheed Martin's SAP or ERP systems would not necessarily be needed, a demand signal as simple as an email or a telephone call would be useful for improving accuracy.

Achieving 100 percent forecast accuracy would affect the transportation section of the supply chain in many ways. First, stock-outs would be avoided with perfect accuracy. If FedEx is unable to provide transportation services because of a last minute request or inaccurate forecast, the customer may go to a different provider for the service. FedEx not only loses the particular sale but also risks losing the customer in the future to a competitor. If a customer is willing to wait the extra time needed for FedEx's service, the customer may be upset with the delay and still turn to a competitor in the future. Marketing and brand perception could also worsen with stock-outs if a reverse halo effect takes place.

Second, product and work quality would increase with 100 percent forecast accuracy. If a company is in a rush to manufacture because a forecast was incorrect, mistakes are more likely to occur because of worker fatigue. As product quality decreases, the company may have to do a recall or replacement that then requires rapid transportation to fix the problem or bring in new materials. The overtime and subsequent fatigue for employees could also potentially decrease morale, strain employee relations, and increase safety and risk issues.

Various costs are affected as well, with the third factor being cost of transportation. Accurate forecasting allows the customer to ship its stock in the most cost-effective way possible that is appropriate for the commodity, which is usually surface transportation. Transportation costs typically go up as forecast accuracy goes down. Wages for labor, the fourth factor, also increase as accuracy decreases. The fifth factor relates to capital. If forecasts are too high, companies may have capital tied up in warehousing space or in raw materials that are not needed. If the company forecasts too low, the ability to get capital in a timely manner at an appropriate rate may be constrained. The company may then have to turn to lines of credit, which typically have a higher interest rate than long term access to capital. Either way, the company has less money than it would if forecasts were accurate, which could subsequently affect the type of transportation used.

Overall, supply chain efficiency deteriorates as forecast accuracy declines. When an expectation is not met, many reactive events occur within the company in order to maintain high-quality customer service. Though a lot of science goes into generating forecasts, their creation is still considered an art because of the multitude of variables and realities that come into play when they are calculated. Though accurate forecasts are difficult to create, the efficiencies gained throughout the supply chain always make it worth the effort to try and improve the accuracy.

4.5: United States Armed Forces – Marine Corps

An in-person interview was conducted with Lieutenant Colonel Christopher Feyedelem at the Pennsylvania State University on December 16, 2010. He is currently a Commandant of the Marine Corps (CMC) Fellow at the Pennsylvania State University and was the Commanding Officer of the Marine Wing Support Squadron 171 from June 2008 to June 2010. Through his roles with the Marine Corps, Feyedelem has had a broad range of experiences within the military's supply chain, from the smallest unit level up to the highest levels of the DoD. The following section summarizes the content discussed with Feyedelem during the interview.

During his years in the Marine Corps, Feyedelem worked with consumable supplies and repair parts for thousands of pieces of equipment, ranging from small radios to very large construction equipment. Forecasts would be needed in order to provide maintenance to external units. All decisions concerning final goods and end items are always made at a higher level within the Marine Corps. Primarily due to the large amount of money required, headquarters is involved in decisions regarding these end items; individual units cannot make the decisions.

To calculate forecasts for repair parts and consumables, the Marines rely on historical information combined with details regarding the operation for which they are preparing. With the historical data as a base, they make subjective modifications using their own personal experiences. For example, if a unit was preparing for a month-long exercise in South Korea, they would start by looking at data from exercises that occurred in South Korea over the previous few years. The Marines' footprint would be analyzed to determine what type of parts and how many had been needed during that time. Those numbers would be compared to the equipment the Marines plan on taking for their upcoming trip, along with variables such as how long they plan on staying and time of year they are going. Additional assessments would be made to take the dissimilarities into account. Because personal judgment and skill does play a role in determining forecasts, accuracy can vary widely if a Marine does not have much experience in the role.

Basic software and simple formulas are used to calculate forecasts. Instead of utilizing large and sophisticated databases or detailed software planning systems, the Marines primarily utilize excel spreadsheets to keep track of data and rough planning factors. There are several reasons for why a detailed set of parameters for forecasting has not yet been implemented. First, there are so many factors that vary between different missions and exercises in the military that it is difficult to take them all into consideration. Second, figuring out a set of parameters, receiving approval from higher levels, and receiving any necessary funding would be very time consuming and could take several years. The Marines have many demands on their time and generally focus on what needs to be done first. Unlike in business, hiring a contractor or consultant is not an option at this level. Finally, in the military, most people do not spend much time in a specific position and instead move around about every three years. If a Marine would like to implement a new system, he would have to build it and implement it quickly before he is moved to another role.

Forecasts are calculated at different times throughout the year depending on their purpose. Before going out on an exercise, forecasts are always calculated to determine what will be needed when they are gone. Forecasts are also calculated in order to demonstrate to higher levels how many consumables and repair parts are needed each year. For example, if a unit provides detailed information on an increased need for POLs (petroleums, oils, and lubricants), it may receive additional funding for its maintenance supplies.

Demand stability tends to differ between consumables and repair parts. Consumables have fairly steady demand and are therefore easier to forecast. The Marines know in advance what their scheduled maintenance requirements will be for their equipment and can plan accordingly. Because of this consistency, they normally receive parts quickly after placing requisitions. For a battalion stationed in Japan, for example, it may take two or three days to receive a part if the battalion is located near a supply unit that has it in stock. If the supply unit is thousands of miles away, it may take two or three weeks. It could take three or four weeks if the supply unit is out of stock and must ship it in from the United States. The more accurately the battalion forecasts requirements, the more likely it will receive those parts on time due to the accuracy's effect on lead times.

Demand for repair parts is generally not as steady. While some trends do occur, a part is often needed only once every few years. There are tens of thousands of different pieces and individual parts for the various equipment, and actions regarding demand are frequently reactionary instead of forecasted accurately. Also, it takes much longer to receive repair parts than consumables. In Japan, for example, it could take over 200 days to receive parts, and some equipment is so old that parts no longer exist and must be fabricated. Marines at the lower levels are not allowed to stock up on repair parts since it would be too costly and run the risk of obsolescence. Each major unit has a supply battalion called a Marine Expeditionary Force that manages the stockage of repair parts and works with the DLA, depots, or vendors to get parts. It is important that the Marines receive their parts on time, since any delay would affect the operational readiness of the unit.

Planners and forecasters must include many different factors when calculating forecasts. They account for the intensity of combat that will be faced to determine if parts will be able to be fixed or if they will be damaged beyond repair and replaced completely. The priority code assigned to parts helps with this analysis, since it provides guidance on whether parts should be repaired or just thrown out when damaged. Product use is considered as well, since equipment in combat goes through tough conditions and has more breakdowns than equipment used in practice or at a garrison. Also, if the parts will be transported through a country like Afghanistan, there is a good chance that the equipment could be damaged along the way. Type of environment affects forecasts as well. Heat and sand in the desert wreak havoc on equipment, making the procurement of greases and coolants necessary. Sand tears up air filters and other parts, meaning more will be needed in these types of environments.

At the battalion level, forecasts are usually between 70 and 80 percent accurate. Ninety percent accuracy is considered very high, and complete accuracy is very seldom achieved. Level of accuracy depends greatly on the experience of the people creating the forecasts. At the battalion level, three or four Marines work on a forecast, and an example would be a maintenance forecast for motor transport equipment. Twenty or 30 Marines work on large-scale projects, such as a forecast for the next fiscal year from the entire battalion's perspective that includes all commodities. No sophisticated tools are used to calculate forecast accuracy. Unlike the repetitive nature of the commercial industry, everything the military does is very different, which makes it difficult to create a tool that could take all relevant variables into account.

Standardization across the Marines, increased communication and visibility, and better software systems would improve forecast accuracy and supply chain efficiency, leading to increased mission accomplishment. Because of lack of time, the Marine Corps does not utilize a standardized forecasting process or system and consequently has forecasts for similar products that vary widely from one unit to another. This variation is exacerbated because units that do not directly work together do not communicate, even when their work and assignments are similar. Because they do not have the time nor initiative to interact, the units do not learn from each other. A specific software system or tool would be beneficial as well but is challenging to obtain because missions and environments change frequently.

Data visibility, however, is starting to improve with a new system called the Global Combat Service Support – Marine Corps (GCSS – MC). The system will replace older legacy systems and enable the Marines to have better visibility. Currently, if a repair part or consumable is needed, the request starts at the supply battalion and goes up the chain of command until an extra part is located or purchased. Units close by may have extra parts, but there is no way to know that information. With the new system, Marines will be able to see which units are holding parts and can reach out for them. The system started being phased in at the beginning of 2010.

With 100 percent forecast accuracy, many factors would be influenced. First, perfect accuracy would affect inventory levels. Safety stock inventory would be completely eliminated, and stock-outs would no longer occur. Cycle stock inventory would become more accurate as well since the Marines would know exactly what levels would be needed based on the lead times of the repair parts and consumables.

Second, labor and work quality would be affected. With 100 percent accuracy, workers would be less strained and would be able to balance their workloads more accurately. Whenever Marines have to react to events, people end up working late or coming in early, and quality of life deteriorates. Balancing the workload reduces stress and causes the workforce to be happier, which in turn increases overall productivity. Wages would decrease as well with accurate forecasts since number of hours worked decreases when productivity increases. This extra time could be spent on training and other activities.

The third factor is risk of obsolescence, which is a huge issue for the military. Obsolescence risk is one of the reasons why the Marines are not allowed to hold repair parts at the battalion level; these decisions are made at a higher level within the Marine Corps. Vendors many times maintain the inventory and set expectations as part of contracts, eliminating the need for units to hold high levels of safety stock that could eventually become obsolete.

Cost of transportation, the fourth factor, is important as well. When forecasts are accurate, the Marines can use much cheaper modes of transportation to ship products, which end up being via ground (truck or ship) instead of air. If they must wait until the last minute because a forecast was not accurate, the Marines may be paying ten times more in expedited shipping costs via the last resort of air. For example, it is much better to be able to contract for fuel six months out as opposed to having to react and try to get an emergency shipment sent out at a higher price than what is necessary.

The fifth factor is warehouse space and its associated costs. Warehouse space can be planned out more accurately when forecasts are correct and lead times known. By not having too much or too little inventory on hand, planners can schedule out exactly how much warehouse space will be needed. The space can then be used as efficiently as possible, which ultimately saves money.

The final factor involves operational readiness and safety issues. Taking out the uncertainty in forecasting means that a unit will have the correct parts when needed, increasing the likelihood that it will maintain a higher level of readiness for its equipment and accomplish its mission. While the Marines will stop a training exercise if the risk is not worth the benefit, in a combat environment, they must sometimes move forward without the needed equipment even though safety is comprised from lack of certain parts. When they cannot move forward, the consequences could also be severe. An example is being unable to fly helicopters in a rescue mission due to a fuel shortage. Because of these repercussions, the United States military tends to keep high levels of safety stock as backups. If forecast accuracy is not perfect, reducing safety stock increases risk.

Overall, all business functions and units are affected by the accuracy of forecasts. While accuracy has an effect on everyone, this information tends to be most important and relevant for the supply section of the supply chain. People in this area use the forecasts the most since they are the ones who work to get funding for the parts that are requisitioned so that they can be ready when needed. The supply section supports a large number of units, and the less reactionary it must be, the more efficiently it can get products through the supply chain and to the Marines so that they can successfully complete their missions.

4.6: Depot – Marine Corps Maintenance Center Albany

Amy Cox, a Program Analyst Leader in the Production Management Department of the Marine Corps Maintenance Center Albany, participated in a phone interview on February 2, 2011. Cox is the forecasting point of contact at the Maintenance Center and an on-site liaison with the DLA. The majority of her work is for the Marine Corps, and all of the products she works with are consumables and repair parts. The section below summarizes the content discussed with Cox during the interview.

The DLA is the Maintenance Center's main customer in regards to forecasting. When creating the forecasts, many factors must be taken into consideration. The replacement factor of the part is determined, meaning that the part could be on a vehicle that is repaired only as needed or that is on a complete rebuild line. There is a list of items that are 100 percent replacement and must be replaced no matter what, while the other parts may not be replaced unless they absolutely need it. Vehicles damaged in battle generally require more replacement than those not used in war zones.

Collaboration among different sections of the supply chain assists with forecasting. As part of the Industrial Forecasting Support Group, Cox meets quarterly with employees from both the Albany and Barstow Maintenance Centers as well as from the DLA. During these weeklong meetings, the group discusses their main lines to determine problem parts and how better to forecast them. Cox also works with the planners who are more familiar with the particular vehicles. A DLA Collaboration Tool assists with calculating forecasts as well. Data is put into a spreadsheet, which is then uploaded into the tool and transcribed into a readable report for the demand planners. Using all of this information, the Maintenance Center is able to provide the DLA with an updated forecast every month.

The Collaboration Tool also determines forecast accuracy, which tends to vary by part and by condition. The demand history of the vehicle plays into the accuracy of the forecast tremendously. If the vehicle has been used for years solely in the United States for training or other similar purposes, that demand history will produce very accurate forecasts for vehicles used in those types of situations. When vehicles are then suddenly sent to war zones such as Iraq, they are likely to be in poorer shape once returned to the United States. All of the demand history is no longer as relevant, and forecast accuracy decreases.

There are many details that the Maintenance Center currently does not receive that would be useful for forecasting. Up-to-date technical manuals for the vehicles would allow Cox to pull information herself to calculate the forecasts instead of having to rely on other people to provide the details. However, most of the vehicles in the fleet are old and parts change so often that the technical manuals have not been updated over the years. Updating the manuals would be time consuming but would make forecasting much more efficient. Additional time in a week that could be set aside to work on the forecasts would help as well.

With 100 percent forecast accuracy, the Maintenance Center would see improvements in many different ways. First, the need to hold safety stock inventory would be eliminated because the items and quantities that the DLA needs would always be known. Inventories would decrease as a result and stock-outs would be avoided. Second, cycle or normal stock inventory would be affected. Instead of ordering parts all at one time, the DLA would be able to order just-in-time

(JIT) by placing orders more often and in smaller quantities. Ordering in higher quantities tends to result in some of the parts ending up as safety stock; smaller order quantities are ideal.

The third factor relates to product quality. If a vendor has been providing the same parts for several years and the requirements suddenly change because of a poor forecast, the stock that the vendor provides may be of less quality. Fourth, the quality of work is affected as well. The current uncertainty that exists in forecasting causes the stress levels of employees to be very high since they know that their work must be accurate to protect the Warfighter. This end goal relates to the fifth factor of safety and risk issues. The longer it takes the Maintenance Center to get the parts necessary to rebuild equipment, the longer it takes to get the needed parts to the Warfighter. Any delay could put the Warfighter in danger.

The sixth factor that would be affected by 100 percent accuracy is the cost of warehousing. With better forecasts, there would be no safety stock and lower levels of cycle stock due to JIT ordering. Less inventory would sit in the warehouse, meaning that other items could be stored or the space could be used for a different purpose. Labor and wages, the final factor, would also be affected since a poor forecast may cause a mechanic to lack a certain part necessary for fixing equipment. The mechanic may be getting paid to wait around for the part since he cannot proceed to the next operation until a prior step is completed with the missing part. Money in labor wages is consequently wasted while time is spent waiting for the needed part.

Accurate forecasts are important to overall supply chain efficiency. If the forecasts are accurate, the vehicles will be able to be sent out as scheduled without delays. A delay at the Maintenance Center would then cause delays in the next section of the supply chain and ripple through to all subsequent entities. The better the forecast, the quicker the vehicle is completed and gets to the customer. Forecast inaccuracy has a negative effect on the entire supply chain.

4.7: Point of Need – Marine Corps Warfighter

An in-person interview was conducted with Major Christopher Cannon on January 10, 2011 at the Pennsylvania State University. Cannon has over 11 years of experience with the Marine Corps and was a Logistics Officer in his most recent role. Through all of his positions, he has a full breadth of knowledge of the Marine Corps from all different levels and has worked with other branches of the military as well. The following section summarizes the content discussed with Cannon during the interview.

To calculate forecasts for vehicles at the battalion level, Marines in Motor Transport and in the Supply Field start by using historical data along with their years of experience in the Marines. Data from missions over the past 12 to 18 months is analyzed to forecast for upcoming missions. The information from the past will show how many vehicles were used and how many broke or were destroyed over that time period. Each Marine also maintains and updates a binder during his time in a role, which is then passed to the next Marine when positions change. These turnover binders can provide valuable qualitative information on the role since a Marine's individual experience and proficiency can affect the accuracy of the forecasts. No formal software or computer system is used at this level, although excel spreadsheets are often used to keep track of data.

Using both historical data and information from turnover binders to complete calculations, the Marines generally calculate forecasts four to six months before a scheduled deployment at the battalion level. This time period is generally long enough to order all necessary parts and pack them while also taking lead time into consideration. Often times, however, the Marines are notified of a deployment less than four months in advance, or the mission involves new factors that have no historical data. In these types of situations, personal experiences are relied upon more heavily.

There are many variables that affect the accuracy of forecasts. Type of terrain, weather, and mission must be fully taken into account. For terrain, factors such as the quality of the road network, sand and blowing dust in desserts, and heavy snow in winter seasons affects how quickly vehicles break and need repairs. Differences between hot, windy, and cold weather also affect the lifetime of a product, as do differences between various types of missions. Vehicles and weapons last longer in peacekeeping and humanitarian efforts, for example, than they do in full frontal combat missions.

The bullwhip effect also affects forecast accuracy. In a battalion, the logistics officers tend to order extra parts to ensure that they will immediately be able to get the products to those who need them without having to turn to headquarters if stock runs out. When stock-outs do occur, headquarters has to place an additional order, forcing the officers to wait until the parts arrive. This tendency causes demand to be overestimated, and the effects ripple back through the organization. Occasionally, in addition to each unit receiving its allocation of parts, the overall headquarters will keep a certain amount in reserve in case more are needed. An example is the Combat Vehicle Appraisement Program that has been used by the Marines in Afghanistan.

Another variable that influences accuracy is human error. Technology and Radio Frequency Identification (RFID) can mitigate error, but containers and products still have the potential of being scanned incorrectly or placed in the wrong location. The chance of human error increases as it moves through more levels and more hands touch the product. As in any organization, theft occasionally happens as well for certain products.

Also, depending on location, items get lost fairly often. For example, since Afghanistan is land-locked, anything needed for Marines in this country must be shipped down Karachi in Pakistan. It then takes approximately 30 days to ship to the exact location via third world country trucks, oftentimes through the jungle truck route. The infrastructure in Afghanistan and Pakistan is fairly primitive, and the truck may arrive completely stripped with the tires punctured. Drivers sometimes encounter warlords who must be paid off or else they will take the containers. It is not uncommon to see the products leave the United States and arrive at the port but never show up at the base.

The logistics sections of infantry battalions generally have accuracy between 75 and 80 percent, with accuracy improving as more data is collected over time. The Supply Management Unit (SMU) tends to have higher accuracy since it orders a larger amount of parts at a higher level. Since the Marine Corps always puts the mission first, forecasts are usually overestimated to ensure that products are available so that the mission can be carried out. While accuracy is important for many reasons, it is particularly vital in identifying trends regarding part breakages and failures. If a part breaks faster than the suppliers says it should, safety centers can classify it as a design flaw and promptly issue a safety message to the Marines to prevent injuries or other harm.

Forecasting could improve with better communication between units. If there are strong personal relationships between units, redundancy is likely to be reduced or eliminated as information about various tasks is shared. Many times, however, a unit ends up working on the same problem that a different unit has already solved, and major inefficiencies result from the lack of collaboration. Aware of the value of this kind of information, the Marine Corps Center for Lessons Learned (MCCLL) was created several years ago in an attempt to improve communication and collaboration. The center compiles after-action reports from all Marines and identifies trends that emerge so officers and units can use the information for future missions.

While there are web-based systems used for the center, the center does not utilize a large online Oracle-based system that everyone can constantly access. Such a system would facilitate the process of finding information relevant to a particular unit, but implementing it would be difficult and time-consuming. Marines are busy with many responsibilities, and such a system is not a top priority. Also, since approval for the software must come from headquarters, the project could take over two years to implement because of the difficulty in defining the scope and passing through all of the bureaucracy. Marines must then be trained on how to use the tool and then mandated to use it.

Like all other sections of the supply chain, the Warfighter would benefit from 100 percent forecast accuracy in many ways. However, the Warfighter's reaction to this accuracy also differs from the reactions of other supply chain sections in several distinct manners. While achieving 100 percent forecast accuracy would theoretically eliminate stock-outs and the need for safety stock, Marines would hesitate to accept a guarantee of perfect accuracy and still over-order. There are so many variables that must be taken into account when creating forecasts that the Marines know it is impossible to calculate them with perfect certainty. This fact, along with the extremely high risks associated with not having enough parts, would cause them to order extras and ultimately continue to contribute to the bullwhip effect. This over-ordering can actually still cause stock-outs if a brigade is given a certain amount of parts and some battalions take more than they need.

Quality of the products is the first factor that would be positively affected by perfect accuracy. Currently, when stock-outs occur, the Marines do not always have enough time to wait for a new part to come in before a mission. They may therefore purchase a similar part from a supplier who can deliver it faster. When many suppliers exist for a part, the Marines are more likely to find an acceptable substitute if the main supplier cannot ship it in time. If a part only has one or very few suppliers, it is harder to find a substitute that is of high quality. Perfect forecast accuracy would ensure that enough time is set aside to always get the parts from the main suppliers. This type of situation is especially relevant when vehicles and weapon systems are being phased out. If the number of breakages and repair parts needed for the entire life of the product is not calculated correctly, the Marines may not be able to repair the product if the supplier has stopped making the repair parts.

The second factor relates to work quality and labor. Individual ability and efficiency of the mechanic will always affect the quality of work completed, but perfect forecasts would mitigate some of the errors. Mechanics would be able to receive the correct parts at the right time, which would allow them to finish assignments without rushing to meet deadlines or relying as much on personal experiences and skills. While wages would not be affected, incorrect forecasts can result in wasted man hours of work. Mechanics may be left waiting around for parts to arrive to repair vehicles and other products, meaning it will take longer to get the repaired finished goods out to the Marines.

Cost of transportation is the third factor affected by perfect accuracy. Different modes of transportation are used based on the priority of the product and how quickly it is needed. A high priority may be placed on a product if the forecast was incorrect. Something may be needed immediately because the forecast did not include it, so delivery will be expedited and costs will increase, especially if air transportation must be used. FedEx Air, for example, may be able to deliver it quickly in a few days, but the costs would be much higher than if it had been sent via ground transportation. If forecasts were always accurate, expensive expedited delivery would never have to be used.

The fourth factor relates to warehouse space and its associated costs. The government provides land and containers, so carrying costs and insurance costs are not relevant. However, supply yards currently carry safety stock inventory that may not be needed. With 100 percent forecast accuracy, the Marines would have lower levels of inventory and would be able to reutilize the extra free space. Each battalion receives a quarterly budget, and the officer would be able to better prioritize the budget to ensure that he can support upcoming trainings and deployments.

Overall, better forecasting leads to a better pipeline throughout the supply chain. Persuading Marines to accept a perfectly accurate forecast would be difficult, but if they see the immediate value and results of it, they would be more likely to accept it and gain the efficiencies associated with 100 percent forecast accuracy. Marines would receive parts quicker and run out less often. The benefits associated with this accuracy would ultimately lead to a higher level of safety and success for the Warfighter as he works to complete missions.

Section 5: FINDINGS

5.1: Current Lack of Forecasting Information

Data gathered from the interviews conducted reveals several areas that, if improved upon, could potentially increase current forecast accuracy. Better visibility and communication both externally throughout the entire supply chain and internally within various business functions was the most common answer among interviewees. Five out of the seven participants consider improvements in this area to be extremely valuable to calculating forecasts and to overall supply chain efficiency. By immediately providing updates and changes to business partners through end to end collaboration, all supply chain entities gain efficiencies that are not otherwise attainable. Also, for sections of the military that perform similar tasks, communicating results would reduce or eliminate redundancy.

The second most popular answer, which was deemed important by two out of the seven participants, was the implementation of an improved tool or sophisticated software system for use by the military. Improvements in this area would particularly benefit the lower levels of the military that currently use very basic tools. Better systems would facilitate calculating forecasts as well as sharing information. This type of improvement would, however, be difficult and time-consuming to implement.

The following five factors each received a response from one interviewee as additional areas that could use improvement. Unlimited funding for programs and parts, standardization among processes and responsibilities, and additional time to complete forecasts and other assignments would all prove useful. Stability of input information and continuously updated technical manuals and materials would also be valuable. If such improvements were made, supply chains would be able to move towards the efficiencies and cost savings that could be gained with perfect forecast accuracy, as are described in the next section.

5.2: Potential Usage of 100 Percent Accurate Forecasts

Each entity of the supply chain was asked about the potential effects of 100 percent forecast accuracy. Various factors involving positive outcomes were listed, with many overlapping. The three main areas include inventory, quality, and costs. Some respondents mentioned factors that would receive no positive effects even when positive effects would theoretically be expected. All participants agreed that perfect accuracy would ultimately help them reach their underlying goal of supporting and protecting the Warfighter. This section describes all of these results in more detail.

The first set of areas that would gain major efficiencies relates to inventory levels. Five out of the seven participants believe that the need to hold safety stock inventory would be completely eliminated since uncertainty regarding demand would no longer exist. Four respondents further noted that stock-out occurrences would subsequently be avoided. Four respondents then commented on the effects to cycle stock. The exact level of inventory needed would always be known with perfect forecast accuracy, meaning that quantity estimations to suppliers would be correct and the right number of parts would be ordered. Also, a just-in-time (JIT) production strategy could be utilized.

Three participants also commented on the effects that 100 percent forecast accuracy would have on the bullwhip effect. Currently, because uncertainty exists and risks are high in the military, order fluctuations tend to build upstream. Military officers over-order to ensure that they will have the needed parts and equipment for their units. This tendency causes an excess amount of inventory to build up as safety stock, and production becomes very inefficient. With perfect forecast accuracy, overestimated demand would no longer ripple back through the supply chain. The negative results of the bullwhip effect would be greatly reduced.

The next two areas would increase efficiencies and reduce costs through quality improvements. Five participants believe that the quality of the products would improve with perfect forecast accuracy. When forecasts are incorrect, manufacturers rush to produce parts, and tooling may have to be switched in assembly lines more frequently. Both situations cause mistakes to be made more often. Products may not meet quality standards and may need to be replaced, or recalls may occur if mistakes are not immediately caught. Also, alternative suppliers of lower quality may have to be used to get the parts on time. Customer perception about quality decreases as well when products are unavailable, which is a phenomenon known as the reverse halo effect. Perfect forecast accuracy would prevent these situations from occurring.

Forecast accuracy would also lead to improvements in worker quality, which was mentioned by six participants. Perfect forecasts would eliminate the need for overtime, reducing stress levels and fatigue as well as improving the quality of life for workers. Capacity planning would be facilitated and less mistakes would occur. Overall productivity would increase because of the improved morale and also because hours of work would not be wasted waiting for parts to arrive. Wages would decrease since overtime would not be needed and the number of hours worked would decrease because of increased productivity. Extra time could then be spent on training and other activities.

The next group of factors all relate to reducing costs through perfect forecast accuracy. First, six respondents agreed that the cost of transportation would decrease. Deliveries are often delayed because of inaccurate forecasts, meaning faster and more expensive air transportation is often used to ship needed parts. Additionally, when quantities constantly change, shipments can be sent using full truckloads. Second, two participants mentioned that the risk of obsolescence would be eliminated. If extra parts are ordered and never needed, money would be lost on the purchase of the parts as well as from the cost of scrapping the materials.

Third, as five participants mentioned, warehouse space and its associated costs would be reduced with 100 percent forecast accuracy. With perfect forecast accuracy, levels of inventory would be lower, meaning that the extra space could be reutilized. If planners knew exactly how much shelf space would be needed, warehouse requirements could be planned out accurately, leading to cost savings. Capital is the final factor related to cost savings, which one participant mentioned. If forecasts are too low, the ability to get needed capital quickly may be constrained. The company may have to use lines of credit, which generally have higher interest rates than long term access to capital.

In contrast to the positive benefits mentioned above, there are two areas that would not improve even though they should in theory. First, perfect forecast accuracy should hypothetically eliminate the need for holding safety stock. There are some instances, however, where components must be purchased in minimum order quantities, and companies must order more parts than are needed and scrap the extras. Money is wasted because of the cost of holding the excess inventory, the cost of purchasing the unnecessary parts, and the cost required to scrap the extra materials. Even with 100 percent forecast accuracy, the company may still have to over order because of the minimum order quantity requirements.

Second, while achieving 100 percent forecast accuracy should theoretically eliminate stock-outs and the need for safety stock, Marines would hesitate to accept the guarantee of perfect accuracy. From their years of experience, members of the military know that there are countless variables involved in calculating forecasts; it is impossible to account for every single factor. This knowledge, along with the high risk associated with stock-outs, would cause military officers to order extra parts even if they were told exactly how many would be used. These actions would then contribute to the bullwhip effect.

During at least one point in their interviews, all participants mentioned how 100 percent forecast accuracy would improve their ability to support and protect the Warfighters in all of their missions. When the uncertainty in forecasting is removed, units would be able to receive the correct number of parts when needed, increasing the operational readiness of the units. Risk would be reduced, and safety would dramatically increase. This accuracy would ultimately lead to higher levels of success for Warfighters as they work to accomplish their missions.

Table 2 shows a summary listing of the results of 100 percent forecast accuracy.

Table 2: Results of 100 Percent Forecast Accuracy

Positive Effects		Respondents	Supply Chain Details
Inventory Levels	Safety Stock	5	Eliminate completely
	Stock-Outs	4	Avoid all occurrences
	Cycle Stock	4	Correct quantity estimations, utilize JIT
	Bullwhip Effect	3	Reduce effects, increase efficiency
Quality	Product Quality	5	Less mistakes, improve quality
	Worker Quality	6	No overtime, reduce fatigue, improve morale
Costs	Transportation	6	Use full truckloads, avoid fast/expensive modes
	Obsolescence	2	Avoid scrapping extra materials
	Warehouse Space	5	Reutilize extra space from less inventory
	Capital	1	Avoid lines of credit with high interest rates
Goal	Support/Protect Warfighters	7	Increase operational readiness of all units

No Effects		Respondents	Supply Chain Details
Inventory Levels	Minimum Order Quantities	1	Required by supplier to order more than needed
	Over-Ordering	1	Marines will order extra anyway to avoid risks

Section 6: LIMITATIONS AND FUTURE RESEARCH OPPORTUNITIES

6.1: Limitations

While the decision to collect primary data ensured that only accurate and up-to-date information would be used in this thesis, it also led to difficulties in collecting the data. Finding the appropriate contact for each supply chain entity and then finding time when the contact would be available for an interview proved to be a difficult task. While a larger amount of interviews would have provided more data to analyze, this constraint limited the number of interviews conducted. Also, as with all primary data collection done through interviews or surveys, answers to questions may have been incomplete. This possibility is especially relevant because of confidentiality agreements that the interviewees must abide by through the very nature of their jobs. Certain figures and pieces of information cannot be shared with the general public.

6.2: Further Research Opportunities

The content of this thesis could be expanded upon in future studies to answer various other potential research questions. The majority of the research in this thesis focused on consumables and repair parts for the JLTV platform used by the Marine Corps. Further research could be conducted on a different weapons system or vehicle platform used by the Marines. Information could also be gathered from different branches of the military and compared and contrasted to the research provided regarding the Marine Corps.

Regardless of type of product or branch of the military, data from more sections of the supply chain would be very useful. Information from additional transportation providers would be particularly valuable, especially from United States Transportation Command (USTRANSCOM). USTRANSCOM is primarily responsible for the transportation piece of the supply chain for the government and the DoD. While the DLA is the supply chain process owner, USTRANSCOM is the distribution process owner (Brletich, 2011). Data from more commercial shippers such as UPS, DHL, and WWX would also be relevant and provide significant insight as well to this section of the supply chain.

Appendix: INTERVIEW QUESTIONS TEMPLATE

Name: ______________________________________	Date: ______________
Supply Chain Entity: __________________________	Time: ______________
Department: _________________________________	Location: ___________
Position: ____________________________________	___________________

Lockheed Martin Forecasting Project – Interview Questions

1. Terms of Confidentiality

The objective of this project is to investigate the potential usage of accurate forecasts for Lockheed Martin products used by the Department of Defense, particularly consumables and repair parts for the Joint Light Tactical Vehicle (JLTV). Maegan Capuano, a senior in the Schreyer Honors College at the Pennsylvania State University, will conduct the interview. The data gathered will be analyzed in her honors thesis.

a. Do you grant permission for the interview to be tape recorded and/or transcribed in order to assist in analysis of the interview data?

Yes _____ No _____

2. Identification of Supply Chain Entity

a. What is your employment background? What previous positions have you held?

b. Which internal business functions and/or external companies do you interact with daily?

c. Does your work involve a particular branch of the military?

Army:
Navy:
Air Force:
Marine Corps:
Coast Guard:
Other area(s):

d. What type of products do you work with? Please elaborate.

Final goods/end items:
Consumable supplies:
Repair parts:
Other(s):

3. Current Forecasting Methods and Techniques

Note: For the following questions, please use consumables and repair parts for the Joint Light Tactical Vehicle (JLTV) as examples whenever possible.

a. What methods and computer systems are used to perform Material Requirements Planning (MRP)? Can you describe or provide a general flow of the planning process?

b. How are forecasts currently generated for the products/parts with which you work? For consumables and repair parts for the JLTV?

c. What type of technology is used to calculate forecasts?

d. How often are forecasts calculated? How does lead time affect the timing of forecasts?

e. What type of demand is generally seen for the products/parts with which you work? (For example, steady demand or erratic demand). How does this affect forecasting?

f. How do planners and forecasters account for the probability of products getting damaged or destroyed in combat? What type of damage is generally expected? When are parts repaired versus purchased new?

g. Are different forecasting models utilized based on product use? (For example, vehicles used in Afghanistan versus vehicles used by the Army National Guard in Pennsylvania).

h. Do seasonal influences or any other types of trends affect your product's forecasts?

i. Which business functions use all of this forecasting information? How is this information relevant to your particular role?

j. What type of tools are used to determine forecast accuracy?

k. How accurate are current forecasts?

4. Lack of Forecasting Information

a. What type of forecasting details would be useful for your position that you currently do not receive?

b. From both a qualitative and quantitative point of view, how would you use these additional details?

c. Why are certain details not available? (For example, too difficult to calculate or lack of communication among business functions).

5. Potential Usage of Accurate Forecasts

a. From both a qualitative and quantitative perspective, how would 100 percent forecast accuracy affect the following factors:

i. Safety stock:
ii. Cycle stock:
iii. Product quality:
iv. Work quality:
v. Stock-outs:
vi. Safety/risk issues:
vii. Obsolescence risks:
viii. Transportation costs:
ix. Labor and wages:
x. Warehouse space/costs:
xi. Overall supply chain efficiency:
xii. Other factors:

b. Which business functions would be affected by 100 percent forecast accuracy?

c. Is there any additional information you would like to provide?

BIBLIOGRAPHY

AeroStrategy. (2010). Industry Insight. In *MRO Forecast*. Retrieved November 12, 2010, from http://www.aerostrategy.com/industry_insight/mro_forecast/

Armstrong, J. S., & Collopy, F. (1992). Error Measures for Generalizing About Forecasting Methods: Empirical Solutions [Electronic version]. *International Journal of Forecasting*, 8, 69-80.

Brletich, Michael T. Personal interview. March 7, 2011.

Eaves, A. H. C. (2002, July). *Forecasting for the Ordering and Stock-Holding of Consumable Spare Parts* (Doctoral thesis). Retrieved November 11, 2010, from http://www.andalus-solutions.com/PhD%20Thesis%20(Eaves).pdf

Enigma, Inc. (2010). Solutions. In *Enigma 3C Platform*. Retrieved November 12, 2010, from http://www.enigma.com/solutions/3c/default.cfm

Feyedelem, Christopher. Personal interview. November 11, 2010.

IBM. (2010). Products. In *Maximo Asset Management*. Retrieved November 12, 2010, from http://www-01.ibm.com/software/tivoli/products/maximo-asset-mgmt/

Lockheed Martin Corporation. (2010a). About Us. In *Customer Base*. Retrieved November 11, 2010, from www.lockheedmartin.com/aboutus/index.html

Lockheed Martin Corporation. (2010b). Products. In *Joint Light Tactical Vehicle (JLTV)*. Retrieved November 11, 2010, from http://www.lockheedmartin.com/products/jltv/index.html

Miro Technologies, Inc. (2010). *Solutions*. Retrieved November 12, 2010, from http://www.mirotechnologies.com/solutions.php?sec=2

Novack, R. (2008). *Performance and Fulfillment Operations Management*. Mason: Cengage Learning.

Pankratz, A., & Woolbridge, J. (2010). Value Based Management. In *Box and Jenkins ARIMA Model*. Retrieved November 12, 2010, from http://www.valuebasedmanagement.net/methods_arima.html

SAP Supply Chain Management (SAP SCM). (2006). Forecast Strategies. In *Croston Method*. Retrieved November 12, 2010, from http://help.sap.com/saphelp_scm50/helpdata/en/ac/216b89337b11d398290000e8a49608/frameset.htm

SAS Institute Inc. (2010). Products & Solutions. In *SAS Demand-Driven Forecasting*. Retrieved November 12, 2010, from http://www.sas.com/solutions/sci/ddf.html

Sheffi, Y. (2002, October 13-16). *The value of CPFR*. RIRL Conference Proceedings. Retrieved January 6, 2011, from http://web.mit.edu/sheffi/www/selectedMedia/genMedia.theValueOfCPFR.pdf

Smart Software, Inc. (2010). Solutions. In *Intermittent Demand Planning and Service Parts Forecasting*. Retrieved November 12, 2010, from http://www.smartcorp.com/intermittent_demand_planning.asp

Surma, J. M. (2010, May 6). *Maintenance, Repair, and Overhaul Solutions*. Center for Supply Chain Research, The Pennsylvania State University Smeal College of Business.

Teknomo, K. (2006). Bootstrap Sampling Tutorial. *Kardi Teknomo's Page*. Retrieved November 12, 2010, from http://people.revoledu.com/kardi/tutorial/Bootstrap/index.html

Thomas Group, Inc. (2010). Services. In *MRO Management*. Retrieved November 12, 2010, from http://www.thomasgroup.com/Services/Operations-Management/MRO-Management.aspx

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