2008 Supply-Chain Excellence Awards

Lockheed Martin Aeronautics Company Submission

Submission Details

Submission Title: Forecasted Raw Materials (FoRM)

Submission Date: January 29, 2008

Submission Category: Award for Supply Chain Management Technology Excellence

Solution Provider Company: Lockheed Martin Aeronautics Company,
Information Systems & Technology

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Section 1 **General Information and Project Complexity**

(1) Provide the name of the submitting organization.

Lockheed Martin Aeronautics Company

(2) Identify the name of the organizational unit.

Information Systems and Technology / Material Management

(3) Provide a brief mission statement of the organization.

Information Systems and Technology (IS&T)
Optimize Lockheed Martin Aeronautics' ability to design, build, market, and support our products through innovative and cost effective information technologies, systems, and services that securely connect all stakeholders to current information, whenever and wherever they need it, in a highly usable form.

Material Management
To consistently exceed customer expectations for best value by sourcing reliable, superior quality materials and services from a diverse industrial network.

(4) Indicate the award category of submission.

Award for Supply Chain Management Technology Excellence

(5) Scope: Provide a brief description of the supply chain and the processes the submission spans.

Lockheed Martin (LM) Aeronautics Company is the prime contractor for the F-35 Joint Strike Fighter (JSF) aircraft program. Within LM Aeronautics, the Material Management organization is responsible for supply chain practices and methodologies supporting aircraft programs. The Information Systems and Technology (IS&T) organization develops IT solutions for business automation and efficiency within LM Aeronautics.

The JSF program comprises a complex, multi-partner, multi-tier global supply chain. The program intends to develop aircraft at the substantial tempo of one aircraft per day at rate production. This production rate produces challenges at every level of the supply chain. At the lowest level of the supply chain exists the raw material suppliers of titanium, aluminum, and composite materials. Raw material suppliers are running at near capacity levels worldwide. Without an accurate forecast of raw material needs from the JSF program, the JSF supply chain will experience part shortages due to unavailable raw materials. This will cause tremendous consequences by disrupting the moving assembly line and impacting aircraft deliveries.

To address this raw material supply chain challenge, Lockheed Martin Aeronautics Company initiated an effort to create an information technology solution to gather required data from various systems and generate a comprehensive, time-phased raw material forecast for the JSF program. The solution is called Forecasted Raw Material, or FoRM application. This effort is an integrated effort covering LM Aeronautics, Northrop Grumman Corporation (NGC), BAE Systems, and their respective suppliers.

(6) External: Provide the names and number of people involved from each supply chain partner organization in the project.

Cytec Engineered Materials
- Gayleen Pigretti
- Michael Lichtwardt
- Bruce Stern
- Andy Taylor (UK)

BAE Systems
- Michelle Crompton

Northrop Grumman Corporation
- John Tolle

(7) Internal: Provide names and the number of people involved from each functional organization and category of each organization.

Lockheed Martin Aeronautics Company
- Mike Jones – IS&T Project Manager
- Jeff Bracken – IS&T Solution Architect
- Alan Lulla – Material Management Lead
- Eddie Blakeman – Material Management (Titanium)
- Michael Wagner – Material Management (Aluminum)
- Scott Lester – Material Management (Composites)

Lockheed Martin Enterprise Information Systems
- Dale Hollingsworth – Development Lead
- Shellie Adamie – Technical Lead
- Development Staff – Four to six developers

(8) Provide a point of contact for each supply chain partner.

Lockheed Martin Aeronautics Company
- Mike Jones
- 817-777-0173
- mike.d.jones@lmco.com

Cytec Engineered Materials
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- 817-801-0115
- Gayleen.Pigretti@cytec.com

BAE Systems
- Michelle Crompton
- michelle.crompton@baesystems.com

Northrop Grumman Corporation
- John Tolle
- john.tolle@ngc.com

Section 2 **Implementation**

(1) Describe the reason that the supply chain project was undertaken and how it was selected.

Lockheed Martin Aeronautics Company Background

Lockheed Martin Aeronautics Company is known for building the finest military aircraft in the world. This recognition has been earned through dedicated research and development of high-performance aircraft and by continuously seeking innovative and low-cost design and manufacturing strategies.

At Lockheed Martin Aeronautics Company, our products play an important role in the defense of the United States and many other countries, and they help ensure peace and stability around the world. Our long list of dependable and highly regarded aircraft includes the proven and affordable fighter, the F-16 Fighting Falcon; the versatile airlifter, the C-130J Super Hercules; the first operational stealth fighter, the F-117 Nighthawk; and the next-generation fighter, the F-22 Raptor. The company has been awarded the contract to build the multi-service, multi-mission F-35 Joint Strike Fighter of the future.

F-35 Joint Strike Fighter (JSF) Program Background

Lockheed Martin is the F-35 prime contractor, while Northrop Grumman and BAE Systems are principal partners in the program. From the start, the F-35 JSF has been an international program, and the unprecedented participation in F-35 underscores that. There are currently eight international partners - the United Kingdom, Italy, Netherlands, Turkey, Canada, Denmark, Norway and Australia participating in the F-35 program.

The System Development and Demonstration (SDD) phase of the F-35 JSF program started with the signing of the SDD contract in October 2001. First flight was conducted in 2006. Delivery of the first production aircraft is scheduled to begin in 2009. During the SDD phase, numerous aircraft will be produced and tested for safety and effectiveness. The JSF program is slated to produce a total of 2,593 aircraft for the United States' and United Kingdom's armed forces.

Supply Chain Challenge:
Raw Material Collaborative Planning, Forecasting, and Replenishment (CPFR)

The F-35 manufacturing environment will experience a production "takt" time, or tempo, intended to generate one aircraft per day when the program is at full rate production. This substantial flow rate requires the extended supply chain to be optimized and well orchestrated to ensure uninterrupted part flow delivery. Part shortages would cause tremendous consequences by disrupting the moving assembly line and impacting aircraft deliveries. Therefore, all efforts must be made to ensure part shortages are minimized throughout the supply chain.

Responsibility for the manufacture of the F-35 major structures is shared across the trading partners, LM Aeronautics, Northrop Grumman, and BAE Systems. In turn, each of the trading partners has outsourced large assemblies and hundreds of component parts to their sub-tier supply chains. This expansive and dynamic confederation of machine shops and fabrication plants create a complex environment for raw material providers.

Each machine shop and fabrication facility generates independent orders for scarce raw materials (composite, titanium, and aluminum) from the primary raw material suppliers supporting the JSF program. The component manufacturers are encouraged to place orders for raw materials with these primary suppliers through the use of "right-to-buy" contracting methods designed to ensure the lowest price possible for raw materials.

While such pricing agreements with the few primary material suppliers helps contain raw material costs, it does little in the way of forecasting how much material will be ordered in a given time cycle. Raw material suppliers are running at near capacity worldwide, creating stressful conditions when trying to fulfill critical orders all while trying to anticipate which type, grade, size, and amount of material should be produced for the next cycle. With the JSF part manufacture distributed into a multi-tier, world-wide supply chain, the aggregation of raw material forecasts becomes essential to help raw material suppliers plan, forecast, and replenish necessary material inventory. Without the needed raw material being produced in the right sizes, at the right time, in the right region, and in the right amount, the JSF program would experience part shortages on its assembly lines as component part manufacturers failed to produce the parts due to lack of raw material.

(2) Indicate the duration of the project. Note if the project was a pilot that is being rolled out. Note if the project is ongoing / still in process.

The FoRM application was developed over a two year period. The first year was 2006 and was strictly dedicated to the development of the strategy, concept, prototype, and requirements definition stages of the project. The second year was 2007 and has been dedicated to code development and tool deployment. The FoRM application was deployed into production on June 14, 2007.

(3) Describe, in detail, the process used to complete the project.

Forecasted Raw Material (FoRM)

To address this raw material supply chain challenge, Lockheed Martin Aeronautics Company initiated an effort to create an information technology solution to gather required data from various systems and generate a comprehensive, time-phased raw material forecast for the JSF program. The solution is called Forecasted Raw Material, or FoRM application. This effort is an integrated effort covering LM, NGC and BAE plus its suppliers.

FoRM has a conceptual architecture that begins with the capture of engineering bill of material (EBOM) information for all component part details from the product data management system. This information includes material type, stock size, and material density data for each part. Additionally, this information has to be captured for each individual aircraft as the specific parts used are unique by aircraft. In the case of composite part information, the FoRM tool is also integrated with a system used by the Mass Properties organization. Mass Properties uses a system to manage the weight of the overall aircraft. By parsing through the data within this system, FoRM is able to identify the material weight information for composite parts by each material used.

With the detail part information gathered, the next step to generating a material forecast is to correlate the right parts and quantities of each part for individual aircraft. Through developed logic, the FoRM tool calculates the quantity per aircraft for each part and associates each part with a specific aircraft. This is accomplished by interrogating the indentured bill of material and marking each condition where a part or assembly is used in multiple locations. This produces the total part list and quantity of each part to be forecasted for a single plane.

The JSF program will build three separate variants of the primary aircraft; a conventional take-off and landing (CTOL model), a short take-off and vertical landing (STOVL model), and an aircraft carrier version (CV model). Each model will be built on the JSF program according to an integrated master schedule. By knowing the exact plan for when each variant model aircraft will be delivered to the customer, it is possible for FoRM to calculate the aggregated time-phased raw material forecast that suppliers will be expected to fulfill. Multiple years of forecasted raw material need is presented within FoRM by material type and separated into monthly aggregate buckets. Additionally, the FoRM application allows for specific materials to be "offset" by a specific number months so that a more accurate representation of material need is displayed within the tool.

With the raw material forecast generated, it must be customized to meet the specific needs of the raw material suppliers as well as the JSF trading partners. By considering the work share responsibilities of the trading partners, the forecast can be looked at as a whole or can be filtered by each trading partner. With Lockheed Martin Aeronautics Company and Northrop Grumman located in different geographic locations within the U.S., and BAE Systems being located within the U.K., the need to segregate the forecast by trading partner and by geographic location was needed. FoRM allows raw material providers and trading partners to see specific forecasts by material for their specific region of the world.

(4) Identify significant challenges encountered, the process for resolution, and the solutions. Identify best practices.

Supply Chain Volatility – At the discrete part manufacturing level, there are numerous machine shops that are used to manufacture the thousands of airframe parts. Each shop may specialize in the production of titanium, aluminum, or composite part manufacture. These machine shops continually emerge and fade as driven by market forces. With part manufacture for the JSF program being subcontracted through our trading partners, and by there suppliers subcontracting the detail part manufacture even further, it became difficult to determine the actual make-up of the JSF external supply chain. To address this obstacle, the team devised a method of gathering the discrete part information from the Engineering Bill Of Material (EBOM) from the common product data management system. Since this repository of data was maintained by the three primary trading partners, then this information represented the parts that would eventually flow into the supply chain of the three trading partners, regardless of which specific suppliers comprised that chain.

Lack of Sub-Tier Supply Chain Connectivity – To further complicate creation of a raw material forecasting solution, connectivity to sub-tier supply chain participants is very limited, at this time. If it were possible to identify and maintain definition of the external supply chain down to the detail part manufacturer level, the cost of implementing a cost-effective data exchange connectivity approach would have been unsupportable. The team decided that the only way to accomplish the project goal was to generate a raw material forecast on behalf of the global, multi-partner, multi-tier supply chain.

Unavailability of Product Development Data for Composite Parts – The product data management system was the primary source for detail part definition which would be used to aggregate the raw material needs by aircraft. The majority of the information required (material specification, material type, stock size, etc.) was readily available within PDM, with one exception. Composite parts had traditionally had their material definition entered into the product data management system with the term “as required” to indicate the amount of material that would be required to manufacture the part. This is due to the extremely different methods used to lay up composite parts in plies of material and then curing those parts in autoclaves as opposed to machining parts from slabs of metal. This lack of product data definition created a significant obstacle. Several process attempts were unsuccessful at capturing this data to supplement the existing product data. Eventually the team realized that the weight of the material used was being managed by the Mass Properties organization. It was determined that the needed weight information for each detail part was being managed within the Mass Properties Data Management System (MPDMS). The interface was then designed and built to merge this information with that from the product data management system.

Determination of Quantity of Parts per Aircraft (QPA) – To generate an aggregate raw material forecast, it is imperative that the amount of material it takes to build a single part is understood. However, since a single part can be used in multiple locations within a single aircraft, the total quantity of each part per aircraft must be determined. The product data management system is very efficient at managing the complex part structure trees that represent a final aircraft, however, querying thousands of records to determine the quantity of each part that would be used to build a specific aircraft would overburden the system’s computing capacity. To overcome this obstacle, the needed product data was captured in an enterprise data warehouse and a formula was devised to navigate the parent-child relationships of the EBOM and to calculate the QPA for each part, for each plane. This information was then used as a multiplier effect when the forecast calculations were executed.

EBOM Degradation on Development Aircraft Programs – Aircraft programs go through multiple phases as they mature into final rate production. During the early stages of a development program, there is intense focus on the initial aircraft being developed that will be used in the flight testing and air worthiness validation trials. At this point in the development process, engineering is not focusing on the product development definition of the aircraft that are to produced two, three, or four years from now. As such, the engineering bill of material for aircraft currently undergoing manufacture or about to enter manufacture are well defined, while aircraft out in the significant future are less defined. This issue resolves itself as the program matures and the focus is moved toward full rate production, but this leaves a problem for generating a forecast for those aircraft whose definition is incomplete. To solve this challenge, the team developed a method within the FoRM application to use “baseline aircraft” to represent the differing variants during the emerging stages of the development lifecycle.

Maintenance of Forecast Variables During Product Lifecycle – The JSF program is continually adapting to supply chain and international partnering opportunities. As the landscape of external partners and work share arrangements change, the tool used to forecast the raw material use must also adapt to accurately represent the program’s needs. For this purpose, the FoRM application has had all of the variables used to generate the forecast implemented in such a way that the owners of the tool can change the controlling variables on demand. This approach allows for new trading partners to be established, for new work share definitions to be created, for “baseline aircraft” options to be engaged or disengaged. All of these features are accessible through a web portal interface to the end user. This ensures that no costly reprogramming will be required as the program matures, thus giving the FoRM application the longest available shelf life possible.

(5) Indicate the metrics used to measure (a) progress and (b) success.

During the development stages of the IT project, traditional earned value practices were used to track the progress of the development effort. Monthly reviews and customer engagement meetings were executed throughout the life of the project. Escalation of obstacles and solutions were vetted and discussed with stakeholders as necessary.

However, the best measure of progress and success was the phased deployment methodology used to deliver the tool. By listening closely to what the customers were struggling with in the area of raw material forecasting, the team was able to devise a plan to develop and deploy the tool in three unique drops of functionality. Each drop would be entirely functional and able to be used immediately in production. Subsequent drops of functionality added to the previous level of functionality, etc. This phased deployment got the tool into the hand of the users faster than traditional waterfall deployment methods. It also provided real life feedback regarding any tool adjustments that could be added to make the tool more useful. Several enhancements were identified early in the project that were able to be rolled into the remaining code drops without additional cost or schedule impacts.

The true measure of success of any IT application is in its use. The forecasts being generated out of FoRM were immediately identified as having a higher level of fidelity than anything produced before. Pricing negotiations on composite and titanium were quickly undertaken. FoRM was instrumental in addressing Air Force concerns regarding out year availability of titanium on future programs and the data was heralded as invaluable. The external composite raw material provider responded to FoRM's deployment by hiring a commodity manager specifically dealing with LM Aeronautics' needs and began investigation of out-year manufacturing capacity to meet the demand calculated within FoRM.

(6) Document and quantify cost and performance improvement benefits.

There are several benefits generated from using the supply chain capabilities supported by FoRM.

Planning and Inventory Replenishment – By generating a forecast for LM, NGC, BAE, and their suppliers, raw material suppliers are able to produce manufacturing cycle plans that ensure an accurate replenishment of the specific materials consumed by the F-35 supply chain. This minimizes excess inventory of materials not needed at a particular time and maximizing availability of required materials. The culmination of these factors produces lower operating costs for the raw material suppliers and lowers the possibilities of part shortages due to raw material unavailability.

Lead Time Management – Certain composite, titanium, and aluminum raw materials have a considerable processing cycle to generate the materials with the specific qualities required to support the stresses encountered in fighter aircraft structures. The processing times, referred to as "material lead time", can become quite extended. The current material lead time for titanium forgings is 26 weeks. With such lead time, it is "hit and miss" for the raw material providers to produce the needed materials to support the program's schedules without an accurate forecast.

FoRM identifies the parts requiring specific materials so that raw material lead times can be planned and managed.

***Pricing Negotiations* –** In an ongoing effort to produce the world's most affordable aircraft, LM Aeronautics Company enters long term contracts with its raw material providers whenever possible. By ensuring the majority of raw material purchases of the F-35 supply chain will be directed to specific raw material suppliers, LM Aeronautics is able to negotiate the lowest possible pricing for raw material. This low pricing is then made available to the extended supply chain through the contracted "right-to-buy" clauses which allow any manufacturer building F-35 parts to purchase the raw material at LM Aeronautics prices. This approach allows the entire supply chain to be cost effective. However, these pricing negotiations are only possible through the accurate forecasting of material need over time. The FoRM application supports this requirement by generating the required forecast data.

***Manufacturing Capacity* –** As the F-35 program enters full rate production, the amount of raw material required to support the supply chain will begin to exceed the current capacity of the raw material suppliers. In responding to this eventuality, the raw material suppliers are using the FoRM generated forecasts to analyze material needs for the next several years and beyond. With the forecast information being able to be filtered by material type and by region, the raw material suppliers are able to assess their capacity to meet those needs with their current manufacturing facilities and locations. As necessary, the raw material suppliers will expand manufacturing capacity within an existing plant or move the production of one material to another part of the world. If it is determined that a single raw material supplier will be unable to meet the comprehensive demand, alternative sources of supply can be considered by the raw material commodity managers of each trading partner.

***EBOM Accuracy* –** Additionally the FoRM application allows for the raw material commodity managers to work with the specific part data as it is maintained within the Product Data Management (PDM) system. This direct interaction with engineering bill of material (EBOM) data allows the FoRM tool to reveal anomalies within the parts list that help improve the overall accuracy of the raw material forecasts. This collaboration between Material Management and Engineering is another benefit to the JSF program by identifying bill of material issues and rectifying them with the appropriate trading partners long before the issues cause downstream complications during the manufacturing process.

(7) Outline how the success of this effort supports organizational objectives described in Section 1, Item 3.

While the deployment of the FoRM tool has been recent, its impact on the Material Management function is already quite noticeable. While the specific details of our raw material provider's contracts and pricing are competition sensitive and can not be released to the public, the following is one example of the impact FoRM is contributing to supply chain efficiency.

Recently a long term agreement was awarded to a composite raw material provider in support of ongoing programs. A contractual obligation was for LM Aeronautics to provide a raw material forecast such as that being generated from FoRM. Though the ability to generate the forecast was only one factor, the raw material supplier and LM were able to negotiate a 28% savings over previously negotiated pricing.

This example exemplifies the joint organizational objectives of Material Management and IS&T. Through the use of innovative technology, highly usable forecast information is produced and consumed by a diverse supply chain in order to ensure raw material is available to meet part manufacture demands. With the FoRM application we have not only met our needs, we have exceeded our customer's expectations.

Section 3 **Knowledge Transfer**

(1) Describe the efforts to share lessons from this effort with other internal organizations.

Composite Part Product Data Availability – Since the successful deployment of FoRM, the challenges of trying to overcome supply chain challenges downstream from missing engineering data in support of composite parts has become more visible. Engineering has now engaged in an effort to modify its practices and to capture stock size information within the product data management system for these parts in the future. They are also committed to convincing the JSF trading partners to also modify their practices to alleviate the supply chain challenges it creates within their respective supply chains.

(2) Indicate how these results can be transferred to other organizations, and specify the likely candidates for transference.

Corporate Interest - Lockheed Martin Corporate Shared Services has expressed interest in trying to adopt a similar FoRM model for potential use by other LM business units. There is thought that there may be additional opportunities for consolidating raw material acquisition at the corporate level.

Raw Material Supplier Imitation - The FoRM tool is so useful to the raw material suppliers that there is consideration by them to create a similar product that they can produce and use when integrating with their other customers. This inspiration to develop a generic, reusable, raw material forecasting tool from the supplier's perspective indicates the successful adoption of a needed methodology and technology.

Summary

Most manufacturing companies traditionally generate raw material forecasts to cover the material needs that they consume internally. However, outsourcing the majority of the manufacturing responsibilities to numerous trading partners and their lower tier part fabrication facilities eliminates the ability of most companies to forecast raw material needs in support of the raw material suppliers. LM Aeronautics Company saw this need and conquered the complexities of the multi-partner, multi-tier supply chain by devising a solution to forecast raw material needs on behalf of its entire world-wide supply chain community. The solution is known as FoRM.