INTEGRATED MANUFACTURING NETWORK MODEL

White Paper

Karl Rojc
Director of Defense Services
California Manufacturing Technology Consulting

May 2, 2011
Background

Since 2005, California Manufacturing Technology Consulting (CMTC®) has been working closely with the Defense Logistics Agency (DLA) to develop, explore, and test new and innovative supply chain approaches to address unmet and challenging part requirements for the sustainment, modernization, and upgrade of legacy defense systems. The primary area of research has centered on the development of an Integrated Manufacturing Network (IMN) model encompassing: reverse engineering methodologies, re-engineering methodologies, and agile manufacturing techniques. Specific part cases in each area are presented here to illustrate and illuminate the components and attributes of this new supply chain model.

Introduction

According to the Defense Logistics Agency (DLA), slightly more than half of the aviation items managed exhibit demand patterns that are so sporadic they cannot be predicted. The lack of predictability together with Diminishing Manufacturing Sources and Material Shortages (DMSMS), often result in lengthy delays at maintenance and repair depots, ultimately impacting defense system readiness. In an environment where low volume and unanticipated requirements are the norm, a highly responsive approach to mitigate the effects of DMSMS is needed. California Manufacturing Technology Consulting has developed innovative approaches, techniques, and solutions for sustainment support of aging defense system platforms. Our approach incorporates an Integrated Manufacturing Network. This approach has proven to be an effective method for addressing DMSMS. The CMTC manufacturing network incorporates linkages to military depots, logistics centers, the DLA, defense system program management, and Engineering Support Activities (ESAs). With these key underpinnings in place, early identification of part unavailability or shortages is coupled with the coordinated development of a new qualified source. An assessment of the baseline condition is made including a determination of the availability and completeness of a Technical Data Package, and the availability of part assets for reverse engineering. Lean and rapid first article development processes are employed to reduce the solution delivery time. The capabilities of the individual manufacturers and service providers within the manufacturing network are then harnessed and coupled to appropriate part support requirements. First article delivery and subsequent qualification are managed by the manufacturing network to provide qualified components to the maintenance activity in the most efficient and expeditious manner. A discussion of the new manufacturing network approach and solutions provided will be presented in case study examples including projects for the KC-135 Stratotanker at the Air Force Oklahoma City Air Logistics Center (OC-ALC). As a model that can be duplicated and expanded, the CMTC manufacturing network approach mitigates DMSMS issues and enhances readiness of defense systems.

Integrated Manufacturing Network

The Integrated Manufacturing Network process is comprised of five (5) primary steps or elements:
- Demand Identification
- Engineering Support
- Agile Manufacturing
- Supplier Matching
- Project Management

Figure 1 shows the interrelationship and flow between the primary elements.

**Integrated Manufacturing Network Model**

**Demand Identification**
- Requirement Identified
- Obtain Additional Information (JEDMICS, DLA, ESA)
- Evaluate Solution Options
- Manufacture To Print?
- Reverse Engineer?
- Re-Engineer

**Engineering Support**
- Identify Appropriate Mfg. Technology & Supplier(s)
- Quality Part Deliver to Customer On Time / On Budget / Meeting Quality Targets

**Agile Manufacturing**

**Supplier Matching**

**Project Management**

California Manufacturing Technology Consulting

Karl J. Rojc

**Figure 1**

**Demand Identification**

The parts needed to support legacy defense systems are many and varied. The first element of the manufacturing network process is to identify appropriate requirements that can be addressed and resolved by the capabilities of the ‘network’. The DLA supports major defense systems - land, aviation, and maritime. When parts and assemblies for these systems supported become difficult to obtain they may become aged backorders. Inserting the IMN approach into the DLA Battlefield Backorder Breakout Initiative (B3I) program has shown that the engineering / manufacturing core that is the backbone of the IMN model is can be powerless to address a parts requirement that is impeded for other reasons.
Another source of demand is at the defense system activity-level either at a logistics depot, and/or with the Engineering Support Activity (ESA). Here, typically is the first and closest point in the sustainment supply chain to the root demand. This is an insertion point where the IMN model has been successful. A more detailed review of the ESA engagement is provided in the Engineering Support section of this paper.

As the demand for parts to support defense sustainment and readiness is significant, the breadth and depth of the issue calls for multiple solutions matched, inserted and utilized with respect to the specific nature of the backordered part or part unavailability.

Although technically not a part of the demand identification discussion, addressing the ‘buy side’ within DLA in is deemed important due to its impact of the outcome of the process. As the primary mission of an IMN is to increase defense system readiness through the delivery of critical parts not available through other more traditional methods, if the solution can’t reach the ‘finish line’ then the concept should be reevaluated. When the root cause for the part unavailability has been determined, and if the appropriate tool to resolve the issue is deemed to be an IMN, then the DLA ‘buy side’ should be integrated into the approach to complete the solution.

Recommendation: For an IMN model to be of benefit to the DLA in the reduction of backorders there must be a cooperative and coordinated effort between the DLA ‘demand side’ and the ‘buy side’.
Engineering Support

Once an appropriate parts demand requirement has been identified, engineering support comes into play. It is here that a determination must be initially made as to the technical approach required to resolve the parts shortage and to permit it to be successfully transferred to manufacturing. In the CMTC IMN approach this element becomes the key bridge to link the defense customer demand with the manufacturing solution. All of the elements of the process are vital, however, the engineering support element requires particular attention as it is coupled so closely with the project outcome.

In Figure 1, the engineering support flow indicates the need to obtain information is the first order of business. Before entering into the discussion regarding reverse and re-engineering it must be noted that it is not the intent of the INM approach to focus exclusively on engineering solutions. Each project undertaken must be being reviewed and subsequently proceed in a manner to minimize or even eliminate the step of reverse or re-engineering altogether if possible as the rapid delivery of parts and assemblies is the core mission of an IMN.

In the course of obtaining information regarding the subject part, it is the first priority and of the utmost importance to endeavor to obtain as much existing technical data and procurement history as can be compiled from all available sources. The best starting point is to have a complete and up-to-date technical data package and one or more assets to review. This desired starting point should be sought and energy at the beginning of every project should be expended to attempt to begin the project at this point.

When this comprehensive level of information is not attainable, the need for reverse or re-engineering comes into the equation.

Reverse or re-engineering is required when an adequate technical data package is not complete or is not available. An asset (a sample of the item to be replaced) becomes the starting point. A simple definition delineating the differences between the two approaches is as follows:

- **Reverse engineering** is the process that captures the physical and technical requirements resulting in the ability to manufacture a part that is identical to the original asset.

- **Re-Engineering** is the process by which a part can be reproduced that is form, fit, and functionally interchangeable with the original asset, however, may differ from the original and is not identical. When modernization and upgrades to parts and assemblies are required, a re-engineering approach is always used.

<table>
<thead>
<tr>
<th>Mission Statement: Integrated Manufacturing Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>To rapidly deliver parts and assemblies to support sustainment, modernization, and upgrade of defense systems.</td>
</tr>
</tbody>
</table>
From the perspective of keeping the approach as straightforward as possible as well as minimizing technical and schedule risk, reverse engineering is generally preferred over re-engineering. However, in some cases the opposite may be true and re-engineering is selected as the preferred approach. The decision between the two approaches often revolves around the quantities required or on material availability. Where materials, processes, and designs can be readily duplicated, a reverse engineering approach is best and that is path that CMTC has followed. In other cases, original high-volume manufacturing processes utilized to produce the part are not practical economically when supplying smaller quantities often associated with sustainment parts requirements. Modernization and upgrade requirements use the re-engineering approach.

**Recommendation:** A reverse engineering or re-engineering approach should be selected based upon both the availability of materials, processes, and designs and with respect to the cost implications vs. manufacturing processes that lower volumes bring. Qualification of a re-engineered part imparts more risk and time into the response equation.

To highlight the reverse and re-engineering approaches two aviation parts managed by the Air Logistics Center – Oklahoma City (Tinker AFB) are profiled here. The first example is a part used on the KC-135 Stratotanker. A dimmer switch assembly used to control the illumination level in support of night refueling operations was no longer available. Rebuilding of the existing inventory had reached its limits and a new part was needed. CMTC reversed engineering the part using an asset that was provided as the baseline. See Figures 2 & 3.

![Figure 2](image1.png)  ![Figure 3](image2.png)

Another requirement at the Air Logistics Center – Oklahoma City was for the B-52 Stratofortress. In this case a re-engineering approach was taken as modernization and upgrades were required. The subject part in this example is a shock mount used in the landing light assembly to dampen the landing impact on the incandescent light assembly – vital for safe night landings. The existing shock mount was developed decades ago and the last production part is estimated to have been built in the early 1960’s. The construction of the current mounts is a fabricated assembly with the material being steel. All parts in service are now heavily corroded resulting in an assembly that does not provide adequate shock isolation. As new replacements for the existing shock mount configuration are not stocked or available, replacement mounts are being salvaged from
the B-52 ‘bone yard’. Unfortunately the replacements are also in the same corroded condition. CMTC re-engineered the part utilizing alternate materials including an aluminum mounting bracket that provides long-term corrosion resistance and an advanced elastomeric material to replace the existing metal spring elements – now badly corroded.

CMTC developed and submitted an engineering drawing to an Air Force logistic engineering activity conforming to ASME standards acceptable to DLA and the DoD. See Figures 4 & 5.

As a part of both the reverse and re-engineering processes, CMTC reviewed and analyzed non-destructive geometry / dimensional capture technologies including the use of coordinate measuring machines (CMMs), laser-based systems, x-ray, and other advanced technologies. Material testing and characterization are performed to identify properties of the material used where documentation is not available or incomplete. CMTC employed non-destructive and destructive methods to identify materials and surface finishes used in subject test parts. Functionality and next-assembly compatibility issues and understanding were reviewed during the course of both reverse and re-engineering efforts.

CMTC created new or updated technical data packages for each part enabling new components to be manufactured and defense system readiness to be maintained. CMTC adopted an approach for the engineering support element of our IMN approach encompassing a range of engineering activities including:

- Gaining a comprehensive system understanding (reflecting multiple design views)
- Exploring candidate options
- Making tradeoffs leading to the selection of a viable re-engineering strategy

In many cases, no technical data exists and the starting point for an engineering project becomes the asset (part to be replaced). CMTC has found that the need for available legacy spare parts is high. With no inventory and when all the existing parts are in use within the defense system, one avenue to obtain an asset is during the period the system is out-of-service for heavy maintenance.
Agile Manufacturing

CMTC has researched agile manufacturing technologies and processes that can be applied to the sporadic needs that occur in DMSMS, aging aircraft, and legacy defense system supply requirements. Pilot projects demonstrated and incorporated techniques such as stereo lithography to speed the solution to the field. Our agile approach to manufacturing faces the reality that we must strive to serve customers with small quantities of custom designed parts with perfect quality, on-time delivery, and at the lowest possible cost. In order to better understand how CMTC incorporates agile manufacturing as an element of our IMN approach presented here it is advantageous to contrast agile manufacturing with the more familiar and traditional production model. See Figure 6.

The dynamics of the agile manufacturing environment vary widely from the production environment. In the sustainment-mode supply chain, that of supplying parts for existing, fielded defense systems and support equipment, the agile supply chain model is required. This is an area we have found that is at times ‘out-of-balance’ within the DLA though work performed on this R&D effort. Earlier, mention was made of the need for a coordinated effort between the DLA’s ‘demand side’ and the ‘buy side’.
When the readiness of complete defense systems is contingent upon the availability of critical parts, the procurement factors of: a.) lead time compression and b.) part availability will more often than not outweigh the factors of the elimination of waste and part cost. However, the procurement modeling currently used is largely based upon production models thus creating a disconnect between what’s actually needed and the tools available to DLA procurement personnel on the ‘buy side’.

The argument for an emphasis on information and knowledge vs. production costs stem again from the need for speed to resolve the needed part as opposed to a long-term planned approach typical of high volume manufacturing. In the case of providing and manufacturing quality replacement parts for legacy defense systems, obtaining the required information and knowledge has more of an impact on costs. This requirement is well-aligned with the discussion in the engineering element of this report where the IMN approach discussed a focus first and foremost on obtaining as much information as possible.

Agility in manufacturing also means implementing rapid manufacturing methods and digital data vs. the traditional capital and labor intensive components of a production supply chain. CMTC has experimented with several rapid manufacturing techniques during the course of this IMN R&D effort. In one example a battery retainer used on a GPS unit that had excessively high failure rates was rapidly redesigned using stereo lithography techniques to prove out the concept in advance of production tooling initiation. See Figures 7 & 8.

**Recommendation:** Many of the DLA buying decisions appear to be based upon a production supply chain model when utilizing an agile supply chain model may reduce the aged backorders and support a higher level of defense system readiness. Requirements for backordered parts should be reviewed based upon the costs associated with their impact to system readiness and the larger maintenance view and then a new financial model for procurement decision making should be applied.

Figure 7

![Figure 7](image1)

Figure 8

![Figure 8](image2)
Supplier Matching

In parallel to the demand identification pursuit producing a part requirement that is a suitable candidate for the IMN approach, the engineering support method determination, and agile manufacturing methods considered, the supplier matching or selection takes place. In this approach element a thorough knowledge of the suppliers in the IMN and their capabilities is required to quickly match a requirement to a supplier both willing and able to take on and successfully deliver the part per specification. This is another area where the manufacturing network approach becomes a new and powerful tool in the DLA’s procurement arsenal. How so? When searching for capable suppliers to respond to urgent or backordered parts for need parts the DLA’s procurement personnel have only a limited amount of time and resources to ‘fix’ broken procurements. An IMN becomes a ‘one-stop-shop’ for DLA buyers, leveraging a larger network of manufacturers. This approach creates efficiencies both within the DLA and with the manufacturing network. In addition, the manufacturing network approach incorporates multiple suppliers for many of the manufacturing methods and capabilities required affording a further layer of redundancy both for cost and availability purposes. Another advantage is that while many small suppliers come-and-go in marketplace, the manufacturing network approach creates a more permanent and stable base for long-term support of defense systems parts requirements. This longer-term, multi-year support is the norm. Furthermore, multiple networks as described here can be established either on a regional basis or by commodities, or a combination of these differentiators resulting in a nationwide ‘footprint’ providing the DLA with a rapid response supply base for sustainment parts.

Project Management

Throughout the entire IMN process the element of project management ties the aforementioned elements together adding value to the process both for the DoD and the suppliers engaged in the process. Project management contributes to a commercial business transaction between the supplier and the manufacturing network. This service frees the supplier from interfacing directing with government contracting and permits them to focus on what they know and do best … manufacturing.
Summary

The IMN model is a new supply chain and logistics approach that can be implemented in multiple manufacturing clusters across the United States to better engage small and medium-size manufacturers in addressing challenging parts requirements needed for the sustainment, modernization, and upgrade of legacy defense systems. The IMN model provides a vital link between defense requirements and manufacturers, and in so doing, has the potential to strengthen the U.S. supplier base for defense. See Figure 9.

Figure 9

Karl Rojc
Director of Defense Services
California Manufacturing Technology Consulting (CMTC)
(310) 263-3084
krojc@cmtc.com