THE NEXT-GENERATION INFORMATION EXCHANGE FRAMEWORK FOR ELECTRONICS MANUFACTURING: THE FRAMEWORK IMPLEMENTATION PROJECT FROM THE GEORGIA INSTITUTE OF TECHNOLOGY'S MANUFACTURING RESEARCH CENTER

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ABSTRACT
It is critical to link all the parts of a manufacturing operation—from the shop floor to the executive offices. The Georgia Institute of Technology's Manufacturing Research Center's Framework Implementation Project (FIP) gives manufacturers a unique opportunity to connect the business side of manufacturing with real-time shop floor information while achieving efficiency, accuracy and significant cost savings. The FIP is using live factory environments to prove that electronics manufacturers can reduce the cost and time of manufacturing their products by decreasing the complexity of communication among shop floor equipment and enterprise applications like ERP solutions. And because a flexible ERP backbone is a critical contributor to the interoperability of a manufacturing enterprise.

Key words: CAMX, ERP, Manufacturing, Communication, Supply Chain, MES

PROBLEM/MOTIVATION

Past National Electronic Manufacturing Initiative (NEMI) roadmaps have highlighted the fact that factory information systems were not adequately supporting the business needs of electronic manufacturers. Typically, the software that runs electronics manufacturing plants suffers from the following challenges:

- Obtaining and exchanging information in the factory floor is expensive and difficult.
- Few commercial off-the-shelf solutions exist.
- The installation cost of a factory application is often several times the purchase price.
- Most factories make use of proprietary, ad-hoc solutions which are brittle and not easily extended.
- Gathering accurate information from manufacturing operations is difficult, but is critical for improving quality and reducing waste.

SOLUTION

Initially, NEMI undertook "The NEMI Plug and Play Factory Project" to address these challenges. The project defined a set of XML messages that can be used to exchange information among systems in an enterprise, independent of the hardware or software makeup of those systems. These messages were standardized by the IPC and referred to as the CAMX (Computer Aided Manufacturing using XML) standards.

After the completion of the NEMI project, The Georgia Institute of Technology's Manufacturing Research Center (MARC), with the backing of several major equipment manufacturers, electronics manufacturers, and software and hardware vendors, established the Framework Implementation Project (FIP) to define how these new CAMX messages would be exchanged. By using the CAMX messages and a standardized method for exchanging those messages, manufacturers can realize a common language that facilitates real-time, efficient sharing of critical business data across the entire manufacturing enterprise.

The FIP team designed, developed and implemented an internet based information exchange solution which makes use of commodity protocols and a single logical message broker. The results of which have been standardized in the IPC-2501, "Definition for Web-Based Exchange of XML Data," which was officially released in July 2003. The

IPC-2501 defines a Message Broker which can be used to easily exchange CAMX or any other type of XML messages in an enterprise. The Message Broker acts as an HTTP server, and software applications and equipment (clients) communicate with the message broker as HTTP clients—just like a browser communicates with a web site. The message broker receives messages from the clients and then routes the messages to the clients that have subscribed to those messages.

PILOTS

In order to test the results of the Framework Implementation Projection in production environments, three pilots have been conducted in actual manufacturing plants. The location and dates of the pilots were as follows:

- Motorola, Seguin Texas, Septemer 2002
- NACOM, Griffin, Georgia, January 2003
- Nortel Networks, Calgary, Alberta, February 2003

Motorola Pilot

The Motorola pilot took place at Motorola's Seguin, Texas manufacturing plant that contains over 40 surface mount technology lines. Representatives from Agilent, Fuji America, Georgia Tech, GTC, Motorola, Siemens, Teradyne and Universal Instruments all participated in the pilot. Six Fuji CP-7s placement machines, a Universal GSM placement machine and five Agilent 3070 testers were used in the pilot. In addition, Motorola's Manufacturing Pulse, Teradyane's SCE, and a prototype Siemens software application all communicated during the pilot. Georgia Tech provided the message broker, equipment adapters and software adapters to facilitate the exchange of CAMX messages. The objectives of the pilot were to verify the connectivity of the framework using the message broker, access the message throughput, assess the ability of the message broker to exchange messages and to document the lessons learned in the deployment.

Within 60 minutes of moving the computers to the factory floor, many of the CAMX applications were operational. During the course of the pilot several hundred thousand CAMX messages were exchanged among the systems participating in the pilot, some in less than 20 ms. Overall, the participants felt the speed and reliability of the CAMX technologies were more than adequate for use in a factory environment.

NACOM Pilot

The second pilot took place at NACOM in Griffin, Georgia and involved representatives from over 12 companies. Some of the companies that participated included: Agilent, Connective Commerce, DEK, Georgia Tech, GTC, MAPICS, Motorola, NACOM, Siemens Dematic, Tech Center and Teradyne. NACOM is a supplier to the automotive industry and fabricates a variety of products, including printed wiring board assemblies and junction blocks for several different companies. During the pilot both surface mount technology equipment and manufacturing lines controlled by programmable logic controllers (PLCs) were monitored. Figure 3 shows the configuration of the pilot. The surface mount technology lines contained DEK screen printers, Siemens placement machines and Agilent 3070 testers. The following software applications also participated in the pilot: MAPICS's Extended Systems, Teradyne's SCE, Motorola's Manufacturing Pulse, Georgia Tech's Message Broker and adapters, and a Siemens prototype line monitoring application.

In addition to the Motorola pilot objectives, NACOM also desired that the pilot would encourage the adoption of CAMX, facilitate the implementation of CAMX by NACOM vendors, further define NACOM's CAMX strategy and assist NACOM in determining the infrastructure requirements needed to implement CAMX. The results of the pilot were very encouraging. Starting with a bare floor and no network hardware, the team was able to establish CAMX framework which allowed the surface mount equipment, PLCs, an enterprise resource planning (ERP) software application, line monitoring applications and manufacturing execution systems (MES) to all communicate through the message broker. The applications that participated in the pilot were written in Sun's Java, Microsoft's .NET, and C++. Several hundred thousand messages defined by the IPC-2501, IPC-2541, IPC-2546 and the IPC-2547 were passed. Some of the messages were exchanged within 6 ms. This pilot further demonstrated the feasibility of the CAX standards.

Nortel Networks Pilot

The Nortel pilot took place at the Nortel Networks' Calgary Systems House in Calgary,Alberta. The systems house conducts final assembly and test of cellular base stations.

The main focus of this pilot was to determine the feasibility of using CAMX to monitor functional test, verify the ability to use third party software to store parametric data associated with functional test, and determine the analysis ability of the third party software with respect to functional test. Representatives form Georgia Tech, GTC, MAPICS, Nortel Networks and Visiprise (Teradyne) participated in the pilot.

The team was able to establish a CAMX framework which received CAMX messages directly from 12 Nortel test sets on the factory floor. Over 100,000 IPC-2547 CAMX messages were received from the test sets and transferred to the MAPICS Extended System ERP application, Visiprise's SCE MES application and Georgia Tech's CAMX framework portal in real-time via the Georgia Tech CAMX compliant message broker. As product was being assembled and tested, real-time charts of product yield and throughput were produced by the various applications. During the pilot, Nortel locations from around the globe were also able to monitor real-time yield of the test sets in Calgary. This lead to recommended future pilots that would take place between Nortel and Nortel's EMS partners in Canada and the United States.

The team was pleased with how the Nortel pilot progressed. Basic connectivity among the equipment and software applications was accomplished before lunch on the first day, and the software applications were presenting the data by the end of the day. This was accomplished with little prior preparation.

Summary of Pilots

The three pilots that were conducted over the past few months demonstrated that CAMX is indeed ready for "Prime Time." The pilots demonstrated that CAMX can be installed quickly, and interact with a variety of equipment and software applications written by various companies. The pilots also allowed implementers of the new technology to exchange ideas and to test implementations with live data.

UPCOMING EVENTS

Another CAMX factory pilot is scheduled for the fall of 2003, demonstrating the ability of an Original Equipment Manufacturer (OEM) and an Electronic Manufacturing Service Provider to communicate over the Internet using the CAMX standards. This may lead to a future technological strategy for the pair.

The CAMX communications solution will also be showcased at NIWeek 2003, National Instrument's annual technical conference and exhibition, being held at the Austin Convention Center in Austin, Texas, August 13-15. Georgia Tech, GTC, the IPC, MAPICS, National Instruments and Nortel will demonstrate how machines and applications can exchange CAMX messages using National Instruments' TestStand product as a final test interface.

INTERPRETING CAMX MESSAGES

The real question is "What do we do with all this data?" Why this data is so important is because we can utilize real-time information for better decision making, to assist customer needs for information, and to keep a tight control on costs. The real-time messages are valuable for quality assurance (i.e. yield), data acquisition (i.e. parametric data), and traceability (i.e. order tracking).

IPC-2541

By utilizing CAMX messages that are sent from individual SMT machines on the factory floor to the message broker, applications can ascertain a wide range of information about how the lines are functioning. CAMX messages such as the IPC-2541 messages ItemTransferIn, ItemTransferOut ItemWorkStart, and ItemWorkComplete can provide specifics about cycle time for each machine, and serialized board traceability.

Messages such as EquipmentStateChange can be used to determine equipment utilization and efficiencies, and b mapping the machine states it can be determined how long a machine has been down, idle, blocked, or executing.
IPC-2541 messages such as WaitingForOperatorAction, EquipmentAlarm, EquipmentWarning, EquipmentError, EquipmentInformation, LaneBlocked, EquipmentStarved, etc, indicate trouble on the line and can be used to alert operators, supervisors or engineers that attention is needed immediately.

IPC-2546

Messages, which focuses on Pick and Place SMT machines, use messages such as ComponentMisPick, MaterialHandlerTrouble, and ItemRecognitionFailure which can provide data for determining if a machine is drifting out of tolerance. By monitoring certain IPC-2547 messages, the of the type of problems as well as how long the problems have been present can be tracked. Additional IPC-2547 messages such as MaterialHandlerLow and EquipmentOutOfComponent, can give early warning messages that provide for faster reel changeovers.

IPC-2547

Messages in the IPC-2547 standard, which focuses on testing equipment, use messages (i.e. ItemProcessStatus) to provide pass or fail information which is valuable to determine yield. The others in the IPC-2547, like ProcessStepStatus address parametric data that can be used for product history or analysis. Even messages like ItemRepair, address the repair cycle for a failed board. These are examples of messages that come off of SMT testers such as automated optical inspection, pin testers, flying probes and X-ray inspection.

Therefore, the real value is to make *faster* decisions – such as catching a component mispick, capturing machine alarms, and feeding statistical process control programs. If applications are listening for issues on the line that alerts individuals immediately (i.e. e-mail or page), then the organization can respond faster to the issues – every second a machine is producing bad product is valuable time and material lost – which costs unrecoverable dollars.

EXTENSION TO ERP

And why not bring this information up a level? MAPICS, a provider of collaborative, extended enterprise applications for manufacturers, joined the program, as a manufacturing-focused enterprise resource planning (ERP) solution provider.

Georgia Tech built an adapter to feed CAMX messages to the MAPICS SyteLine 7 application, providing shop floor status data to the SyteLine 7 production module. Since this module feeds inventory, costing, and other financial modules, SyteLine 7 can track current positions of customer orders, know inventory levels and reordering, and provide up-to-the minute decision-making information.

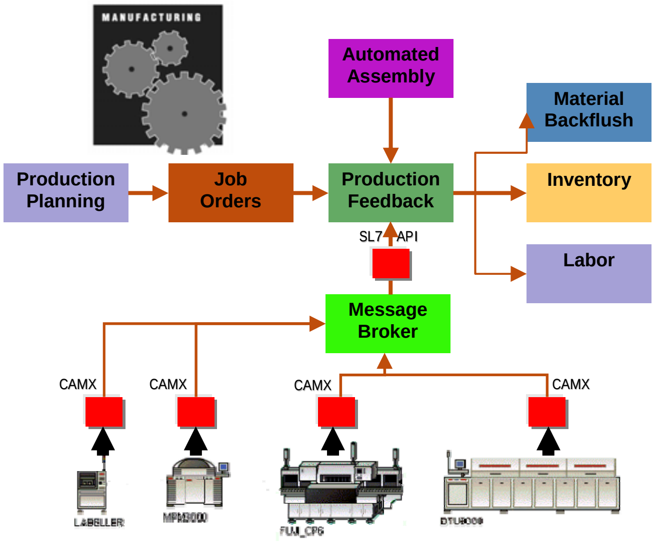

Figure 1. SyteLine receiving CAMX messages.

Through the CAMX SyteLineadapter that Georgia Tech developed, SyteLine connects to the message broker and receives a myriad of CAMX messages that can provide timely information used for Work in Process (WIP) positioning, product movements, completions, product quality, yield and scrap. Having real-time information that feeds an ERP system is invaluable to a company's financial position, since immediate feedback updates inventory levels, cost data, and labor. Thus, the faster product can be shipped out the door the better return on investment.

Now, at this higher level, the purchase order cycle could be automated, so when the inventory level of components are low, order schedules could be sent to vendors in a just-in-time (JIT) manner to replenish stock. Instead of using old, slow electronic data interchange (EDI) methods, RosettaNet standards (www.rosettanet.org) can be used to transmit purchase order requests and receive an acceptance in minutes.

Currently, Georgia Tech is working with MAPICS to build automated RosettaNet PIPs to quickly transmit information to suppliers and customers to speed up supply-chain communications. What was just a great concept will now be a reality – quicker, better, cheaper ways to tie data together into useful and productive information. Through this effort, Georgia Tech has built a SyteLine workflow adapter to feed the automated RosettaNet PIPs (Georgia Tech started with the Purchase Order transmittal, the RosettaNet 3A4 PIP) to transmit information from an OEM to EMS suppliers requesting replenishment of board components. Accessing SyteLine's database of information, the adapter pulls the latest details to feed the 3A4 PIP XML definition. Then, it sends the message via the message broker to route it to the respective EMS or component vendor. The next segment is that the EMS or component vendor accepts the PO and creates an internal customer order, checking all of its rules and ordering policies, and issues a 3A4 acceptance response back to the OEM. In this manner, an effective supply-chain communication scenario can be illustrated utilizing commonly accepted standards, such that RosettaNet has created for the industry.

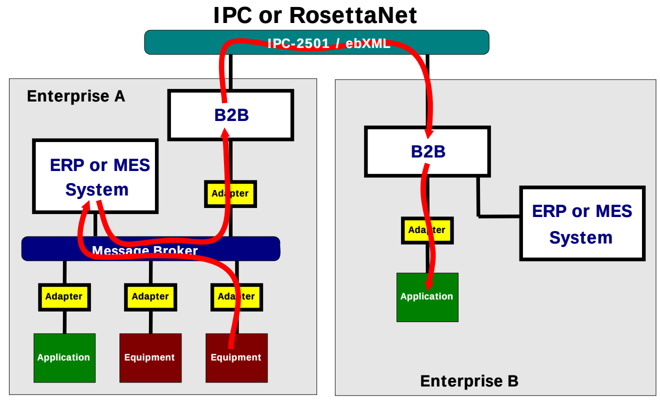

Figure 2. Supply Chain Communication.

Another communication standard that is being used by the team is the Product Definition eXchange (PDX) where a product like a computer board is described in a product structure view. The IPC PDX standard provides a definition of the product item, bill of material (BOM), approved vendor, etc. Please see http://www.pdxstandard.org for additional information about the PDX. PDX is widely used in PDM systems to transmit product definition data from an OEM to their EMS partner. PDX is also used for communicating engineering change notices (ECNs) to suppliers since it allows for red-lining of a item build.

Georgia Tech is currently building an adapter that takes files based upon the IPC-2571 and IPC-2578 standards and builds the product configuration in SyteLine by dynamically establishing the product characteristics. In this manner, SyteLine can illustrate how product design information can be shared among business partners that can collaborate on the design and building over the web.

CONCLUSION

Through several successful Framework Implementation Project pilots, it has been shown that the CAMX standards are ready to assist manufactures in reducing costs and complexity of exchanging data within the enterprise. In addition, the Product Data Exchange (PDX) standard and Rosettanet PIPs can assist enterprises in exchanging information with other enterprises. This efficient exchange of data allows corporations to accomplish many positive things such as:

- Allowing for the quick configuration of equipment and applications through communication based upon standards.
- Providing customers with a view into manufacturing operations through web-based portals.
- Enabling early identification of problems, reducing failures and rework.
- Being more responsive to new product introductions and engineering change orders.

- Meeting customer expectations by monitoring processes in real-time.

These standard based solutions are available, have been shown to work in real factories, and are being implemented by companies involved in the Framework Implementation Project. Other forward thinking companies could profit by following their lead.

ABOUT GEORGIA TECH

The Georgia Institute of Technology, also known as Georgia Tech, is one of the nation's leading research universities, providing a focused, technologically based education to nearly 15,000 undergraduate and graduate students. Georgia Tech has many nationally recognized programs, all top-ranked by peers and publications alike, and is ranked in the nation's top ten public universities by U.S. News and World Report. It offers degrees through the Colleges of Architecture, Engineering, Sciences, Computing, Management, and the Ivan Allen College of Liberal Arts. As a leading technological university, Georgia Tech has more than 50 interdisciplinary research centers that consistently contribute vital research and innovation to government, industry, and business.

ABOUT MAPICS

MAPICS is the largest global solutions provider focused exclusively on manufacturing. Building on more than 25 years of industry experience and proven success, MAPICS helps manufacturers be world class by gaining market share, operating at peak efficiency, and exceeding customer expectations. MAPICS solutions include software-extended ERP, CRM, and supply chain management-and professional services. The solutions are implemented on the two industry-leading technology platforms-Microsoft and IBM.

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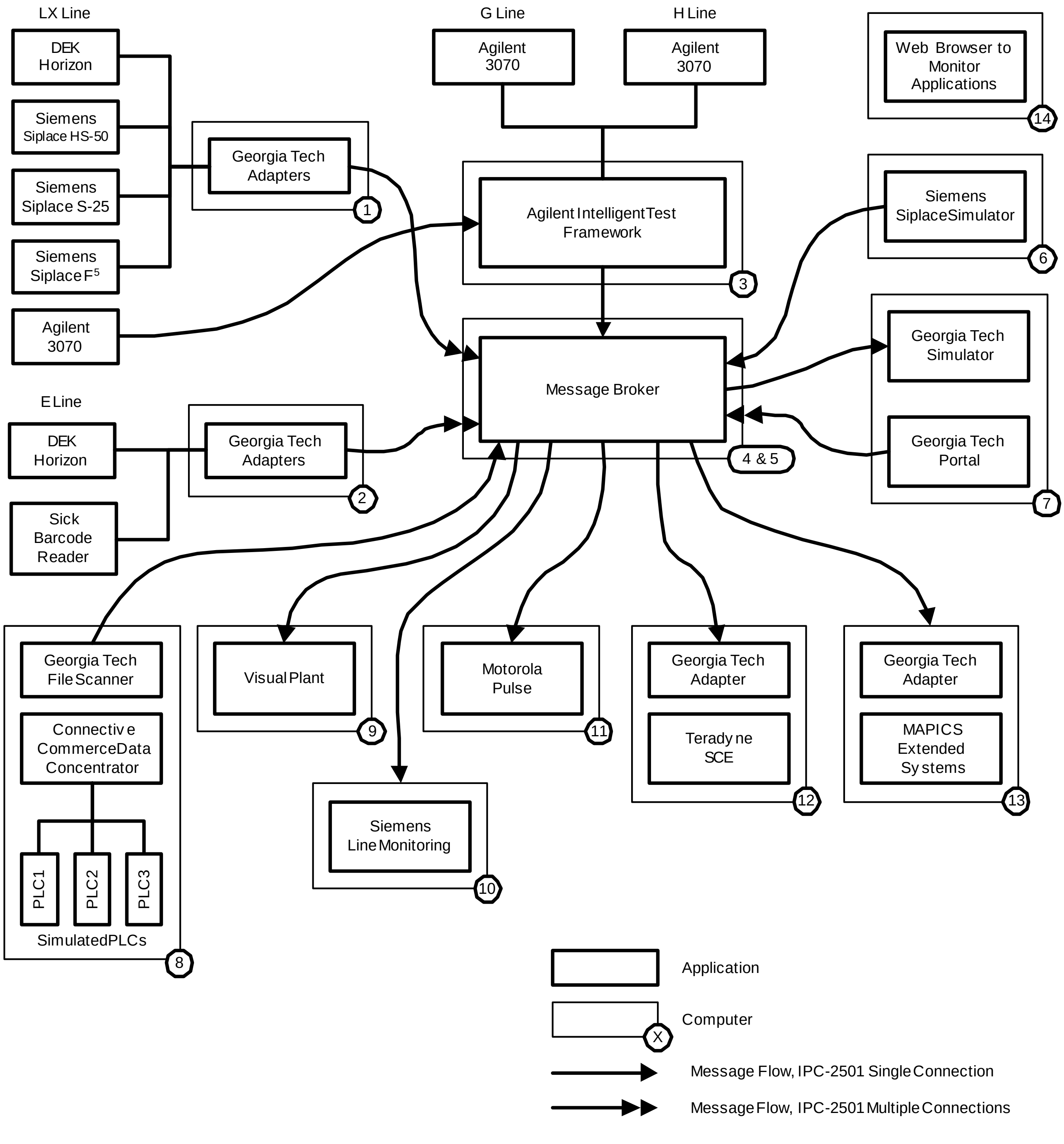

Figure 3. The NACOM Pilot System Under Test.