About the Author

Michael McClellan has over 30 years of experience serving and managing manufacturing enterprises. He has held a number of positions in general management, marketing and engineering, including President and CEO for a multi-division equipment systems supplier. In 1984 he and a group of associates founded Integrated Production Systems, a company that pioneered the use of computer systems to manage and track production events on the plant floor. His first book, *Applying Manufacturing Execution Systems*, defines manufacturing execution systems and explains the reasoning and history behind them. He is a frequent speaker at companies and manufacturing conferences, has presented a number of papers on plant information systems, and holds one patent. He has recently completed a new book, *Collaborative Manufacturing: Using Real-time Information to Support the Supply Chain*.

He currently lives in Washington state and is President of Collaboration Synergies Inc., an advisory company providing consulting services in the area of collaborative manufacturing system development and implementation, plant floor information systems and manufacturing execution systems.
Electronics Industry Collaboration

The US electronics industry is estimated at over $550 billion in annual sales and is made up of more than 2500 companies. The industry ranges from computer manufacturers to government electronics to consumer products and telecommunication equipment manufacturers and their suppliers. The industry is pervasive, affecting our lives wherever we are. There are more that 400 million Internet users worldwide and over 500 million cellular subscribers. It is difficult to imagine how the world economy would function without computers and communication systems that we now take for granted. It is obvious this is not a monolithic industry where everybody is doing the same thing, but there are some business issues that do appear to be consistent or at least widespread.

This is a global industry with manufacturers on every continent with supply chains and design teams that are operating 24 hours each day seven days per week. A major trend in this industry is the greater emphasis being placed on volume manufacturing plants in regions such as Central Europe and Asia, particularly China. This brings the requirement for product and process portability across continents as volume manufacturing is moved from new product introduction facilities to volume plants in these regions. This portability requires additional collaboration with respect to product and process data between plants.

Product lifecycles can be very short. Time to market for a new product is a critical measurement of nearly every company. Products that once had a lifecycle of 18 months now have an average profit lifecycle of 6 months.

As innovations reach the marketplace, consumer prices are slashed and profits almost eliminated. According to one study, improving time to market by one month can improve profits by 11.9%. Tools that can shorten the time for design and manufacturing ramping are in strong demand.

Design and engineering changes are especially important in the electronics industry. The importance of design collaboration in electronics is realized by the emerging RosettaNet standards for high technology design and manufacturing. The RosettaNet cluster 2C for “Product Design Information” contains the following six definitions of Partner Interface Processes or PIPs:

- 2C1 Distribute Engineering Change Status
- 2C2 Request Engineering Change
- 2C3 Distribute Engineering Change Response
- 2C4 Request Engineering Change Approval
- 2C5 Notification of Engineering Change Order
- 2C6 Notification of Engineering Change Implementation

Many companies are outsourcing manufacturing to reduce capital investment and focus on core competencies of design and marketing. One example is the estimate that over 50% of all semiconductor products will be outsourced to third party packaging and foundry houses by 2010. Doing so will require product content information to be shared, modified, and managed across a global value chain network. This also requires third party manufacturers to provide close collaboration networks with customers to maintain confidence that production is in line with expectations.

The inventory pipeline, which is estimated at one year of sales, can have multiple versions of a product in process between initial vision and customer delivery, all of which are very susceptible to engineering change and market demand variables.

The bullwhip phenomenon can have a devastating effect that contributes to false shortages of material and erratic ordering patterns. Demand information collaboration for supply chain synchronization is becoming an integral part of the industry relationships. In early 2001, collaborative manufacturing was brought into focus when Alan Greenspan remarked, “the same forces that have been boosting growth in structural productivity seem also to have accelerated the process of cyclical adjustment. Extraordinary improvements in business-to-business communication have held unit costs in check, in part by greatly speeding up the flow of information. New technologies for supply-chain management and flexible manufacturing imply that businesses can perceive imbalances in inventories at a very early stage--virtually in real time--and can cut production promptly in response to the developing signs of unintended inventory building.”
Many companies have used acquisition strategies to build market share and to gain capacity. Integrating the various facilities into coherent manufacturing process pipelines is a continuous and unrelenting effort.

Collaboration is alive and doing very well in this industry. One example is the earlier described activities of The National Electronics Manufacturing Initiative (NEMI) and their effort to develop industry-led standards to provide easy inter-operability and transfer of data to and from production facilities. NEMI’s Plug and Play Factory Project was created to develop an open, vendor-independent environment for electronics assembly, inspection, and test equipment. The project addressed the issues of how to quickly integrate new pieces of electronics assembly equipment into a shop floor line management system and how to manage the vast amounts of data available in today’s electronics manufacturing environment. It also addressed issues relating to the collection of shop floor data from disparate pieces of equipment and how that data could be transferred between remote locations via a Web browser. Activities focused on three areas:

- Definition of standards for a software framework that will allow interoperability among software and equipment produced by different vendors
- Development of process-specific machine communication interface standards for surface mount equipment.
- Establishment of a test bed to prove the concepts developed by the project

Central to the Plug & Play effort was development of a software framework, based on XML (extensible mark-up language), the universal format for structured documents and data on the Web, which encodes data into a format that is both human and machine-readable. This platform independent and vendor neutral framework provides a common interface among all the hardware components on a printed circuit board manufacturing line, enabling equipment and software from various vendors to work together in a seamless fashion. It also allows data to be collected from all the machines on the line — regardless of vendor or location — and displayed inside a Web browser.

Three standards XML (CAMX) were developed by NEMI’s Plug & Play Factory Project to facilitate interoperability among hardware and software components used in the manufacturing process (see Table 1). Based on XML, these standards provide a common interface among all the hardware components on a printed circuit board manufacturing line. They also leverage GenCAM, the industry standard that defines how product data for printed circuit boards should be described, including information needed for tooling, manufacturing, assembly, inspection, and testing requirements. These standards are available at [www.ipc.org](http://www.ipc.org).

<table>
<thead>
<tr>
<th>Standard</th>
<th>Title</th>
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<tbody>
<tr>
<td>IPC-2541</td>
<td>Generic Requirements for Electronics Manufacturing Shop-floor Equipment Communications Messages (CAMX)</td>
</tr>
<tr>
<td>IPC-2546</td>
<td>Sectional Requirements for Shop-floor Equipment Communication Messages for Printed Circuit Board Assembly</td>
</tr>
<tr>
<td>ICP-2547</td>
<td>Generic Requirements for Electronics Manufacturing Test, Inspection and Rework Equipment Communication</td>
</tr>
</tbody>
</table>

The use of product lifecycle management systems has been deployed extensively in this industry to manage the flow of engineering and product information across the supply chain. As the product lifecycle continues to shorten and the supply chain broadens, there is more information that must be shared with more partners over wider distances faster. Some of the daily issues include:

1. Ensuring that the precise current definition of the product is being communicated to all internal and external partners in real time.
2. Knowing the current cost of the product and the effect of changes in development, production, or procurement?
3. Reducing the time for new product introduction and the time to implement product changes.
Early development of collaborative product development tools centered on the storage and management of engineering information and the maintenance of a central repository that was accessible to those with correct credentials. This has matured where today’s applications include extensive abilities to manage change across the extended enterprise and gain real-time feedback from manufacturing resources to confirm the as-built information. Some of the broader impact can be seen in these examples:

- With engineering facilities located in the US and manufacturing facilities in China, Honeywell was able to reduce their scrap rate by 50% through reducing their time to effect product changes faster and avoiding making nonconforming products.
- Verifone was able to reduce their product change cycle time from 25 days to two days across 11 engineering and manufacturing facilities.
- Microsoft was able to take advantage of a product lifecycle collaboration system to develop their Xbox console by sharing information among 200 suppliers. “Anytime a change occurred, we used the system,” said Todd Holmdahl, General Manager Xbox Hardware. “This enabled us to communicate information to all parties involved in a vigorous formal way whenever something changed on the motherboard. The last thing you need when you’re doing something as fast and as complicated as Xbox is to have compatibility problems with your technology, or not to have someone in the communication loop. Collaboration technologies are important in that they give you a formal way to communicate.”

Another example of state-of-the-art manufacturing systems in today’s collaborative environment is Nokia Networks, a part of the Nokia Group with headquarters in Espoo, Finland. Nokia Networks is a leading infrastructure supplier for the mobile internet. According to Jouni Juvonen, Team Leader, Nokia Information Management, Nokia Networks, the Production Line Control and Monitoring (PLCM) system controls the entire execution of shop orders and makes real-time manufacturing data visible on company’s internal web. The PLCM project addressed several critical needs in the areas of new product introduction, manufacturing agility, and information systems integration. The PLCM platform helps the company fulfill its goal of being a leading global network infrastructure provider. Some of the main benefits of PLCM include enabling lot size of one manufacturing, recording complete product build history, providing real-time process monitoring, and managing quality data.

Ericsson Radio Systems AB of Sweden has also demonstrated effective supply chain collaboration. They produce radio base stations, devices used to make up the cellular telephone system infrastructure. The order lot sizes can range from 1 to 500 for anyone of 3000 different product permutations. Typical customers include AT&T, Vodafone, and other telephone service providers.

The system, originally implemented in 1999, is used to manage and track customer orders from order receipt to 4th tier supplier authorization. The capable-to-promise decision can be determined within 10 seconds of a request based on a current view of capabilities within the supply chain. The order information is then sent throughout the extended enterprise to the currently connected 25 first tier suppliers, 10 second tier suppliers, one third tier and one fourth tier supplier.

Mr. Pontus Andersson, VP of Customer Configuration and Logistics Centre, offers these comments regarding the system and its development over the past two years:

“It was necessary to rely less on forecasting and, instead, focus on tools for operational control.”

“The tools that were implemented allowed members of the supply chain to optimize themselves for the benefit of the entire supply network.”

“Event driven execution solutions could take a company or an entire supply chain a giant step closer to a frictionless flow of material through true supply chain collaboration.”

“The system was not designed to be a window into our suppliers’ world to serve as a means by which we could control and second guess them. Instead, the system serves as a window into Ericsson’s world for each of the suppliers. They are provided with real-time demand information and parameters for replenishment.”
The following statistics were offered:

<table>
<thead>
<tr>
<th></th>
<th>Traditional Supply Chain</th>
<th>Full Supply Chain Vision</th>
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</thead>
<tbody>
<tr>
<td>Order Lead Time</td>
<td>15 days</td>
<td>2 days</td>
</tr>
<tr>
<td>Inventory turns</td>
<td>5</td>
<td>90</td>
</tr>
<tr>
<td>On Time Delivery</td>
<td>20%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Total Indirect Cost</td>
<td>100</td>
<td>90</td>
</tr>
</tbody>
</table>

A major driver of collaboration activities is the rapidly evolving practice of contract manufacturing. Many companies, large and small, are turning to sources of manufacturing expertise to help develop, manufacture and ship their products to the end user. These companies are typically never heard of, but manufacture more and more of today’s electronics products. While companies such as Intel, Sun Microsystems and Cisco are almost household names today, the EMS companies such as Solectron, Celestica, Flextronics and Sanmina-SCI are not so well known. A typical contract manufacturer can serve as many as fifty different companies from one facility providing services that range from simple assembly of shipped in components to full product responsibility that includes design for manufacturability feedback, material sourcing, product test and record management, packaging and shipment to the end user.

From the perspective of the contract manufacturer one might imagine the tasks necessary to maintain management control over incoming inventory, scheduling, product changes, customer shipment information, and quality assurance. What started as a simple assembly process for test or overflow capacity has become a deep collaborative effort between companies with global multi-facility manufacturing capability serving many different customers such as Intel, Sun Microsystems or Cisco Systems.

Companies in this business recognize the need to use collaborative tools from a number of perspectives:

1. Internal processes to maintain their own management control systems must be above typical standards. The argument made by the contract manufacturer is they can do a better job by focusing on a core competency of manufacturing. Since that is the primary value they bring, the ability to perform is the center of management effort. The contract manufacturer must be everything and more than a company might expect from their own facilities.

2. The relationship with a number of high level customers each with their own set of suppliers, engineering changes, and varying end user customer requirements suggests an environment with many continuous touch points and an anticipatory posture that effectively deals with every contingency before the moment of crises on the plant floor.

3. Issues of culture and truth are just as real in this industry as any other. The ever present concern of “How do I know my product is being produced correctly and on time?” is pervasive and must be accommodated.

The answer is total openness and complete electronic connection for everyone. Collaboration is at the center of this industry: ERP systems linked in real time. Product lifecycle management systems installed with like systems or extensions at contractor sites, supplier locations, and customer location are common. MES solutions are now able to collaborate directly together to avoid the filtering that takes place once information is fed to higher level layers such as ERP or planning functions. Engineering change order management systems that can effect different lots within the manufacturing pipeline is the norm. On-line assembly and test data is available to a variety of secured observers. And in some cases cameras are in place allowing the customer to actually see their products being assembled and tested.
Equally as important as the in-house management functions is the view for the customer. New product introduction requires information exchange and engineering change orders on a frequent basis, sometimes many times each day. It is not unusual to expect order, assembly, test, packaging, and delivery of $100,000 plus customer orders within three days with supply chain response time of two hours from order placement to material delivery. Keep in mind this is not an exception but is the normal operating procedures in many parts of the electronic equipment industry. The requirement for real-time processes and results information to be on-line and available to the customer is obvious.

The question is how to provide the sense of security that everything is happening according to plan everyday. The answer is total openness and complete connection electronically for everyone. One company uses an extensive product lifecycle management system to link every node including customers and suppliers into a real-time network. If a customer or a supplier does not have a system in place they will furnish it as an extension of their own. If the customer has a system that is non-compatible, they will develop the link so information can be transferred bilaterally. The PLM system is set up with product information and process information relative to each facility since a plant in China may have different processes that in California. This allows each production facility to see and manage processes on a local basis.

There has been a significant amount of detail in the chapter on industry standards indicating how far the idea of collaboration has taken this industry. The efforts by NEMI to provide easy “plug and play” connections for manufacturers in a supply chain has already brought significant rewards. As this industry continues to focus more on core competencies of design and development and deal with ever shorter product lifecycles, collaboration with a wide range of supply chain partners seems to be the obvious direction to take. With major companies like Intel, Sun Microsystems, and Cisco Systems leading the way it will be difficult for other organizations to not keep pace.
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Substantial information was furnished by Andrew Robbie and Alan Fraser of Teradyne Inc.