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.
Product Lifecycle Management

Product lifecycle management describes collaborative information systems used to manage the information and events associated with a product from concept through design through manufacturing through distribution and recycle; it also includes user feedback processes. The capabilities of an effective system enable interaction between departments within a company or an extended enterprise of value chain partners.

This category of collaboration currently goes by many names including product lifecycle management, product chain management, collaborative product commerce, collaborative product development, or collaborative product data management. Sidney Hill, Jr., Executive Director of MSI magazine, describes this area of collaboration as a class of software and services that use Internet technology to permit individuals to collaboratively develop, build, and manage products throughout the product lifecycle.

The market is currently very upbeat with major suppliers rapidly growing their product offerings. Current enthusiasm is obvious in this comment by Kevin O’Marah of AMR Research: “The idea of using collaborative technologies to support product development across extended groups of experts is irresistible. It’s too good an idea not to do.”

Modern applications of product lifecycle management are built around a closed loop process that begins with customer requirements information management and concludes with collection and management of customer feedback information to start the process over again. These systems have evolved from early computer aided design (CAD) and computer aided engineering (CAE) to product data management systems that support and connect global network nodes with proactive system tools built around creating, storing, and managing product and process information across the extended enterprise. The use of the Internet provides a global reach that can include real-time interactive sessions with participants anywhere.

Collaboration is based on the idea of interactive co-development and management. Participants in co-development may be within a company sharing information between product development, manufacturing, marketing and purchasing. Extend that to a multi-plant company and then to a multi-company enterprise. In many businesses the participants include suppliers and their suppliers and it is not unusual to include customers and their customers at some points in the process. Some companies have hundreds of people involved on product project teams that can last for years.

In discrete item manufacturing there are two phases of product collaboration. The process begins with product definition starting at the earliest concept of the product. This includes every step in the design and every detail of the product ranging from the bill of material listing of components and their suppliers, to recipes, routings, tooling requirements, assembly methods, and process parameters. All documentation and software that is connected to or used in the manufacture or product use is part of the product definition.

The actual production of design information is usually accomplished through collecting and blending information from various engineering and design sources. The design competencies can be brought together in a virtual conference room to review documents, make changes, and keep current through immediate access to previous session information. This collaboration can include such diverse groups as customers, suppliers, marketing, manufacturing, and professional designers able to work concurrently and collaboratively on design issues. Information can be imported from various CAD sources and presented in 3D form providing easier knowledge sharing and a common view. A particularly important part of the process is the ability for manufacturing process and tooling design as well as other departments to participate in the early phase of product development. The cost of a product is estimated to be between 60% and 80% determined at the time of initial design. Collaborative design tools allow participation at an early development stage with a wider range of participants at the time when input relative to cost can be more effective. This early input can have a significant effect on reducing changes later in the development cycle.
The second major category of product lifecycle management is the management and processing of the product design information through the production and delivery processes across the supply chain network to customer delivery and product disposal. This includes managing issues across the supply chain such as product change, engineering change orders, product and product information obsolescence, data integration and entry into and from the ERP system, product service and improvement, sourcing management and tracking, and material and information flow. Functionality can include collection and distribution of product process data generated during production including who, what, and when for each step in the production process, logistics, delivery, maintenance history, and customer use. In some industries this can include details such the name of an operator at a supplier’s plant, laboratory test results for a specific lot, complete genealogy data for each item in the bill-of-material, and it could extend to maintenance information as provided by the end user or a third party service provider. The next illustration provides an outline of the many collaborative instances and the continuous process that can occur throughout the life of the product.
A recent study by the Original Equipment Suppliers Association (OESA), an association of suppliers to the automotive industry, was done to build an internal business case for collaborative product development. The study focused primarily on the efforts within the industry to collaboratively design and manage product information. The study group listed some current state conditions that were felt to be opportunities for improvement.

1. Document access and retrieval can be cumbersome. Because information is handled by e-mail, fax, and mail there are frequent routing errors, lost information, extended approval cycles and resubmission due to incorrect or missing information. There can also be considerable time delay and different revisions in the systems at one time.

2. Considerable documentation and data are generated during the life of a development program. The data tends to reside with the author/owner and is distributed when needed. In many companies common documents are available; however, substantial effort may be required to access documents because there is no central repository of information.

3. Customer satisfaction is often compromised by timing delays resulting from the need to interpret multiple formats of information, and the lack of a common distribution approval process. The processes cannot be easily automated as information and capabilities are contained in separate systems with no interface capabilities.

4. Communication and program data errors are common due to multiple data sources containing inaccurate or out-of-date information. Multiple versions of documents may also exist within the design systems but there is no mechanism to guarantee the latest information is being accessed by team members.

5. Data and documents are generated by many sources. The document owner must be contacted each time to ensure that the document in question is correct. This is not always possible and errors occur when old or inaccurate documents are used. Team membership over the life of a program may change and documentation may be lost in the transition of new team members.

6. Maintaining accurate records of product version status among all supply chain members working on a specific project can be complicated, error prone, and the cause of continuous frustration. Additionally, the viewing of CAD drawing data is generally limited to individuals with CAD access requiring paper copies for anyone else needing to review the data. This lack of access often results in duplication of activities, a lack of organizational learning, continuous improvement, root cause analysis and the inability to balance resources.

7. The inability of product development teams to access pertinent information for decision making in real-time results in delays and non-optimal decisions. In addition, most suppliers do not have standard revision control over design information or the ability to review past information.

8. Program data and information are not centralized resulting in ineffective use of product development resources searching multiple repositories for such information and associated timing delays. Additionally, lack of centralized data across multiple products limits opportunities for commonality of parts, tooling, equipment, and technology.

9. In many cases archiving of hardcopy documents is done using minimal indexing data. Data is then stored in hardcopy boxes. Usually only the employee’s name, data and one or two word descriptive text of the contents of the box is available. Current lack of document control methods can create legal exposure.

10. Companies usually store data on shared local area network (LAN) hard drives. Data is often duplicated across locations. Confusion and conflict occur as a result of not knowing which version of a specific document is the latest or the correct one.
The study went on to outline direct benefits of using a collaborative product development system.

1. **Collaborative design allows participants of an interactive design session to discuss design concepts and direction.** Several concepts may be developed and discussed in a single interactive session using an on-line system. Design teams may interact via a Web browser and review several variations of a design done interactively using input from both the customer and in-house design teams. This interaction allows a free exchange of ideas and concepts. The ability to collaborate with colleagues in different locations around the world results in the best ideas being exchanged simultaneously, reducing re-engineering efforts and the best product offerings at the lowest costs throughout the program.

2. **Faster product development cycle times (fewer design turns) and greater efficiency also result from automated workflow, 24/7 capability, and effective sharing and visibility of common information.**

3. **Many suppliers believe that the potential exists for significant reductions in product development time using collaborative tools and processes.**

4. **Workflow functionality can ensure that necessary follow-up actions take place, thereby avoiding potential delays and allowing engineers to meet key milestones.**

5. **Real-time review and approval of data and program related information allows customers, suppliers, and internal users to improve efficiency and quality through earlier design involvement and participation.**

6. **Travel times to discuss feasibility and review designs can be substantially reduced. Teams will be able to mark-up and annotate designs and provide manufacturing feasibility in a real-time capacity.**

7. **Using workflow to manage access and approval of designs in a central repository would reduce cycle time in the development process and facilitate informed decision making.**

8. **A collaborative development system will allow process/procedure tracking and an audit trail useful in ISO 9000 certification. This same audit trail can be used in a “lessons learned” review for process improvement**

9. **New employee effectiveness can be enhanced as a result of the pre-defined workflow process, documentation availability through a central repository and virtual workspace.**

10. **Standardized processes for completing development tasks can be communicated more effectively within organizations.**

The situation is similar in many companies and industries and the task of managing product data becomes more difficult as the geography and number of interactive partners increases. Some companies make such extensive use of collaborative product applications that they have developed formal contractual relationships with supply chain partners. Cisco Systems Inc. uses a process among major supply chain partners that spells out responsibilities, procedures, delivery dates, statements of work, and dispute resolution methods. There is also a three level management structure made up of the project managers and development teams, a relationship management committee and a joint executive sponsor from each company.

Flextronics Corporation is a global electronics manufacturing services provider that serves major electronics original equipment manufacturers. As an integral part of the supply chain of a wide range of companies, it became necessary to develop an evaluation process where both they and the customer examine the relationship and how it will be managed. These formal agreements among collaboration partners are common, but most instances of collaboration are less formal relationships built on historical ties or company competencies.

Agile Software is a provider of product lifecycle management systems with extensive capability to collect and manage product information and provide a direct interface with manufacturing facilities and supply chain partners. Their system is divided into the following six modules: Product Definition, Change Collaboration, Supplier Management, Design Integration, Manufacturing Integration and Partner Synchronizing.

**Product Definition** enables a company to create, maintain, re-use, and share core product information and make the information instantly available on-line to any member of their extended supply chain partners. This will provide each partner with immediate access to the latest information and enable them to:

- Locate preliminary and released information about any part, document, or engineering change.
- Create, view, and redline a bill of material.
- Identify where multiple parts or documents are used.
• View which items would be affected by a change.
• Send changes, parts information, or documents to a reviewer.
• View released and pending changes.
• Generate reports based on product definition.

Change Collaboration automates the product change process, enabling users to create and approve changes online. Supply chain partners can collaborate in real time throughout the product change process, providing shorter change cycle times and reducing time and cost in the manufacturing process, and thus enabling them to:
• Create, route, modify, and approve change requests through a web browser.
• Notify reviewers when a change is ready to be reviewed.
• Keep supply chain partners involved in the process.
• Manage and control the change with a workflow system.

Supplier Management allows manufacturers to collaborate with their supply chain network to make decisions regarding quality, cost, and availability of components, both during new product introduction and over the product lifecycle. They can:
• Define commodity components and their manufacturers for each bill-of-material item.
• Control and communicate changes to the approved manufacturers list.
• View data sheets and files associated with a manufactured part or the manufacturer.
• View the released and pending changes to a part’s approved manufacturer list.
• Identify duplicate part numbers and consolidation opportunities.

Design Integration enables companies to quickly and efficiently share engineering data with manufacturing by seamlessly connecting and transforming data from multiple CAD sources. Companies can:
• Aggregate and transfer data from disparate CAD tools.
• Improve the new product introduction process.
• Improve the product change process.
• Enable the ramp-up of manufacturing resources.
• Simplify the aggregation of raw product information.
• Make critical product chain information available for immediate use to other systems.

Manufacturing Integration publishes product chain information from the system to a wide variety of enterprise business application and users both internally and across the extended enterprise. Businesses can:
• Synchronize manufacturing with up-to-date detailed product information.
• Increase information availability and accuracy across the supply chain network.
• Integrate the data with enterprise business systems.

Partner Synchronizing is a tool that publishes critical product information to the supply chain network partners using Product Data eXchange (PDX). This allows customer, supplier, and design partner to participate in the review and approval process by providing product data to a wider variety of business applications and users. Partners can:
• Publish critical information to supply chain partners without regard for system compatibility.
• Send and receive PDX documents in real time.
• Eliminate manufacturing delays caused by incomplete or old product information.
• Make better decisions using the most current information that everyone can work form simultaneously.

The business value of these systems is broader than the obvious idea of a community of stakeholders sharing information. There are extensive business benefits that come in a number of forms. These are just a few.
• Businesses can develop and introduce new products faster. With the full product design always up-to-date and available for collaboration from entities anywhere within the supply chain, it is easier to make revisions to products under development or to authorize changes to existing products. With the consolidated information it is easier to convert engineering information to manufacturing information.
• There is special value during new product introduction and manufacturing ramp-up by maintaining a current database of problems, workarounds, and changes with easy visibility. This allows quick information exchange between the manufacturing process and the design team with interactive re-
sponses from anywhere in the extended enterprise.

- Product shortages and replacement options can be met with a quicker response due to predetermined part compatibility and source information.
- Engineering change orders can be more effectively issued and tracked across the supply chain.
- Part genealogy and production information can be aligned with production lots or serialized product item numbers.

Product lifecycle collaboration is not just for discrete product manufacturing companies although that is where the earliest implementations and most growth has been. Process industries including specialty chemical, pharmaceutical, consumer packaged goods, and food and beverage producers also use this technology to distribute and maintain product information across global plant locations and third party manufacturers. A consumer goods manufacturer with 16 manufacturing sites requires visibility of information and on-line collaborative between product development, the various manufacturing facilities, and the many supply chain partners. Daily production issue resolution is the same here as in most businesses but is compounded by variations in raw material and by the subsequent adjustments in recipes and processes. It is also not unusual to update and reconfigure products to stay current with the market, consumer tastes, or competition. This involves collaboration across the enterprise to react collectively and quickly.

Process industry applications begin at early laboratory phases and continue through introduction into manufacturing, with that cycle being repeated numerous times for innovations and changes during a product’s life. For process companies today that is a mostly sequential series of steps that pass a product from department to department. At each step, product data is passed in an unstructured, ad-hoc way to the next department, resulting in delays and costly errors. Industry-wide standards for product definition, such as CAD, are not available as they are in discrete industries like electronics and automotive. This results in longer time-to-market and time-to-manufacture periods causing companies to lose valuable time in the early stages of new product innovations when margins are the highest. A related problem is that new product portfolios are not organized for a collaborative environment nor are they consistently judged against objective criteria making go/no-go decisions more complicated and subjective. Unstructured product definitions, a lack of a collaborative environment and inadequate information required to fully prosecute manufacturing options result in products that are committed to a specific manufacturing location early in the process, leaving little room for flexibility.

The value propositions in both discrete and process industries are very similar and are based on achieving real business benefits that increase the profitability through increased revenue, decreased risk, lowered costs and better utilization of assets. The following system application information was provided by Sequencia Corporation, an early supplier of product lifecycle systems in the process industries

**Increased Revenue** - Accelerate the delivery of product innovations to market and increase product innovation throughput. (50% improvement from the current range of 12-24 months.) Companies gain market advantage over their competition by getting product innovations to market more rapidly. In addition, they increase innovation throughput without increasing investment costs.
- Complete product visibility and collaboration capability from design through retirement
- Automated research & development tools

**Decreased Risk** - Increase the success rate of the innovation portfolio. (100% improvement from the current success rate of 10-40%)

- Comprehensive portfolio management
- Broader view to design for customer need
- Internationally recognized standard product definitions
Lowered Costs - Increase the profitability of products by minimizing product cost structures. Increase the profitability of new products by ensuring that the products are introduced with the most competitive product cost structure.

- Integrated design for manufacturability
- Optimized least cost recipe configuration
- Strategic material substitution and consolidation capabilities

Better Utilization of Assets - Avoid capital expense by more flexible utilization of available assets. (Current capacity utilization is frequently as low as 50%.) Customers can achieve a greater return on assets by fully utilizing all of the capacity and capability that is available in the value chain, both internally and externally. Capitalize on more market opportunities by adding the flexibility to enter new markets without the risk of adding additional manufacturing assets.

The system is made up of several integrated modules that can be used independently or individually.

- Standards for communicating process industry product definitions – Similar to CAD in the high tech world, the system is the enabler for providing a common language (S88 via XML) for developers of products to communicate among themselves and with supplier and manufacturing facilities, either within or outside the product company.

- Complete specification requirements – Defines all aspects of the product, including formulation and packaging, presented both graphically and digitally. The system supports specialized requirements such as nutrition and labeling for food and beverage and multiple packaging configurations for CPG.

- Rationalization of manufacturing capability – Model any target manufacturing facility either company-owned or contract by allowing the users to define hundreds of attributes and capabilities. Using the detailed information in the system, product requirements can be compared to plant capabilities, including qualified contract manufacturers, to select plant assets as an ongoing process or, in the case of an acquisition, map new products to existing plants and old products to new plant.

- Intra- and inter-company collaborative Workflow – The processes involved in collaborative product design and deployment can be configured for each collaborative partner.

- Portfolio Management – All of the information collected for a product from all of the collaborators in a product, including marketing studies, lab results, cost estimates, etc. are collected under a unified project, making decision analysis for any particular product visible and accessible.

- Visibility into enterprise applications – In addition to providing visibility into whom, where, and how a manufacturer can make a product, supply chain and/or ERP information can be accessed and used to make critical decisions.

- Efficient transfer of product information through the process – Defines the products and manages the process so that all information collected and required to move a product through various departments within and without the enterprise are available in a common system. Product companies must know from there manufacturing options, both within and without, which can make a product, where they can make a product, and how they make a product.

- Innovation Process Management – Product innovation processes are developed and defined to ensure best practice processes, reduce handoff times and to allow for clear accountability and continuous improvement. Best practices such as stage-gate processes can be defined and enforced through project workflow, routings and approvals for all elements of the innovation project. Business processes become more transparent providing clear accountability and a fully documented decision trail to allow for continuous improvement through the creation of a full audit trail of discussions and decisions.
• **Design for Customer Need** – Product innovations are defined with market requirements that are made clearly visible to all authorized collaboration parties. These market requirements, which represent the customer’s needs, are an inherent part of the design. The requirements are directly tied to the product characteristics and product specifications required to meet the customer’s need. The specifications, in turn, are directly tied to testing procedures required to ensure that the customer needs are met at every stage of the design process. This ensures that the customer will rapidly embrace or accept the product innovation when it is introduced.

• **Project Collaboration Portal** – Personnel across organizational boundaries have full access to projects via the web. According to security rules, they can quickly see the status of the projects they are assigned to and the actions required. From the workbench, they can view project goals, access project documents, product information and view project discussions. In addition, personnel will be proactively informed of new project information through alerts and subscriptions that will allow them to proactively manage current projects or new projects that may impact them.

• **Portfolio Management** – Projects are clearly defined and characterized in a central project repository allowing projects to be analyzed and prioritized relative to each other to achieve the optimal portfolio mix in terms of value maximization, balance, strategic alignment and organizational focus. The project portfolio is fully visible to allow projects to be objectively compared, allowing companies to accelerate the projects destined for market success and reduce the time and money consumed on projects that are destined for failure. By focusing on fewer, more strategic projects companies can increase the success rate of market winning ideas and focus precious resources on the highest value projects.

Another supplier has identified these specific benefits for companies in the food industry.

• A central, global repository minimizes search time, increases formula reuse, and shortens time to market. Product development information maintained includes: formulas, specifications, raw materials, test results, etc.

• An implementation of standard work processes globally to improve product consistency and shorten time-to-market.

• An actively managed R&D pipeline through real-time visibility into project status, budgets and resource allocation. A making of decisions with the latest information and apply portfolio management techniques to the product portfolio.

• A reduction of non-value added activities through standard business processes.

• A reduction of redundant development and testing by leveraging past micro, toxicology, stability, analytical and compatibility test information.

• An elimination of duplicate effort by reuse of existing projects specifications, raw material or formulas.

• Capture data in a structured format enabling you to quickly search the global database by properties of raw materials, formulas, specifications, requirements, development projects and programs, and test data.

• Security capabilities which provide secure access to internal and external users within the product development system.

• Integrated modules that enable the secure outsourcing of portions of your product development processes, leveraging technology from global research centers, universities, and technical consulting resources around the world.

• Consistent data through a single, scaleable database and data structure as the foundation for e-commerce initiatives, thus providing a means for customers to give firsthand product performance feedback and product improvement ideas.

• Leverage existing product information to respond faster to new requests; a search of existing formulas and specifications for a starting point to new requests—search formulas that never made it to production.

• Leverage product and process strengths; differentiated products and improved value-added relationship with customers.

• More accurate and effective estimates of cost.
There are many examples of collaborative applications in today’s business press and this story in the MSI magazine publication Impact of March 2002 tells the story very well. The global aerospace and defense manufacturer BAE Systems launched its collaborative development efforts by creating a Shared Data Environment, or virtual community, with about 600 participants including the data exchange infrastructure needed to enable project partners to collaborate through all phases of a product lifecycle—from early design through manufacturing and in-service support. Ian Haddleton, Integrated Systems Solutions Manager for BAE Systems says, “With products as complex as a warship, the days of single source are over. Increasingly, our major projects involve a multitude of stakeholders, and in order to deliver our product on time and to cost, it is imperative that we are able to share information easily and openly with one another. To make this happen we did two things. First, we agreed on a set of values with our customer that are now the guidelines and principles for anyone working on the project—i.e., wherever possible information will be shared openly, risks and concerns will be shared early. Second, we established an infrastructure that would support these values, the Shared Data Environment. We now work as a true team, within our own company, with other project partners, and with our customer.” Currently there are about 600 people participating in the on-line community. This number is expected to grow to 1000.

The ability to share information among a large community of designated users simultaneously is fundamental to the intent and definition of collaborative manufacturing. Product lifecycle collaboration is one way to substantially broaden the talent and experience that can be used to address change, development, and product problems all across the various stages of a product life from the earliest concept through manufacture and use, and back to the design process for improvements. Some industry analysts suggest system implementation growth rates exceeding 40% per year.
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