BUSINESS TO MANUFACTURING (B2M) COLLABORATION BETWEEN BUSINESS AND MANUFACTURING USING ISA-95

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ABSTRACT

Integrating business and manufacturing is a key process for manufacturing companies. Integration requires that that business process and manufacturing process exchange commonly understood information, yet this must be accomplished without unnecessary impact to the existing business processes or manufacturing processes. The ANSI/ISA-95 Enterprise/Control System Integration standards define an effective model to meet these goals. This paper reviews the ISA-95 standard, the benefits of using the standard for integration, and XML schemas based on the standard.

Summary

This paper defines the economic reasons for business to manufacturing integration, some of the key business drivers that require integration, a definition of a standard for integration, who will benefit from the standard, and a brief overview of the standard for business to manufacturing integration.

Keywords: ERP, PLM, SCM, MES, Integration, Manufacturing, XML, Standards, ANSI/ISA-95

1 INTRODUCTION

Integrating business and manufacturing is a key process for manufacturing companies. Manufacturing departments must quickly and efficiently build the right products, at the right time, for the right markets. This requires correct and timely information to manufacturing from the rest of the business, and it requires timely and accurate updates on actual production from manufacturing to the rest of the business. Integration requires that that business process and manufacturing process exchange commonly understood information, yet this must often be accomplished without unnecessarily impact to the existing business processes or manufacturing processes. In addition, the integration must handle the diversity of manufacturing and business systems in a typical company. This paper defines a model for MES, PLM (Product Lifecycle Management), ERP (Enterprise Resource Planning), and SCM (Supply Chain Management) integration that can be applied to a wide range of discrete, batch, and continuous manufacturing industries.

2 BUSINESS REASONS FOR INTEGRATION

Effective integration is important to a company when it is tied to the company's key business drivers. "Key business driver" is a term often used in connection with strategic planning and related goal setting. Key business drivers are the areas of performance that are most critical to the organization's success. Some examples of the key business drivers and how they relate to business to manufacturing integration include:

- Implementing "Available To Promise" processes

  An "Available To Promise" (ATP) process is achieved by providing order takers (sales and distribution channels) access to inventory and production capability information, so that they are able to commit to reliable delivery dates in real time. Implementing ATP may be a key business driver because companies that consistently fail to meet their promised delivery dates, will lose business to more reliable suppliers. Some companies that have focused on their ATP processes have reduced late and incomplete shipments from over 70% to under 3%, thereby dramatically increasing customer satisfaction and improving the companies' profitability.

Implementing ATP processes requires near real time visibility into production capability. Manufacturing information needed for automated ATP processes include:

- Current finished goods inventory.
- Current production plan for that product.
- Realistic capacities of the production facility of that product.
- Raw material inventories.

➢ Reducing manufacturing cycle times and asset efficiency

One key measure of a company's efficiency is manufacturing cycle times and inventory turns. This is a direct measure of the efficiency of manufacturing assets. To reduce cycle time a business must first identify areas where most of the delay and waiting occurs and then address them appropriately. Information from manufacturing must define actual data on the production capabilities and throughput of plants, areas, production lines, process cells, and production units. This allows effective allocation of assets to products, integration with planned maintenance, and better inter-site and intra-site planning.

➢ Implementing supply chain optimization

The key business driver of reducing raw material and final product inventory is implemented through supply chain optimization. Supply chain optimization covers four main areas: Source, Make, Deliver, and Plan, as defined by the Supply Chain Council - www.supply-chain.org. No effective and optimal schedule can be built without knowledge of current and planned available capacity and detailed knowledge of actual production throughput for different products. Supply chain optimization also requires that the manufacturing departments run on near real time schedules, often receiving schedule updates several times a day. Implementing supply chain optimization requires the following exchanged information between the business functions and manufacturing:

- Currently committed resource capabilities
- Currently available resource capabilities
- Future committed resource capabilities
- Future available resource capabilities
- Actual resources required per product and per production segment

➢ Implementing activity based costing

Activity Based Costing (ABC) is a process that attempts to assign cost to specific segments of production (such as assembly, inspection, and packaging) by product, in order to determine the true cost of production per product. Activity based costing allows companies to determine what products are profitable or unprofitable so that they can make decisions on pricing, outsourcing, and investments. Exchanged information required for activity based costing includes:

- Actual material resources used per segment of production per product
- Actual timing of personnel, equipment, and energy uses per segment of production per product

➢ Reducing in-work inventory

In work inventory can be a serious drain on a company's capital investment, yet it is often a problem hidden from normal financial review. Reducing in-work inventory requires knowledge of the actual state of product production and levels of intermediate materials. These need to be reported on a regular basis so costs can be determined, bottlenecks identified, throughput improved, and in-work inventory reduced. The book The Goal by E.M. Goldratt provides a good reference on the benefits and methods for reducing inventory.

Integration of business and manufacturing systems can have an impact on an entire economy, even when implemented by a small percentage of companies. Experts on the USA economy have tied much of the recent rise in productivity to Information Technology (IT) and reductions of inventory. For example, the USA Federal Reserve Chairman Alan Greenspan said on June 14, 1999, "*… But the recent years' remarkable surge in the availability of real-time information has enabled business management to remove large swaths of inventory safety stocks and worker redundancies and has* *armed firms with detailed data to fine-tune product specifications to most individual customer needs.*" These impacts have been felt despite the estimate that only 20% of companies with more than $500M USD in annual revenue have installed SCM (AMR Research).

3 A STANDARD FOR INTEGRATION

In order to achieve the benefits listed above, some means for integration is required such that:

- The method is complete enough to handle most interactions.
- The method separates business processes from manufacturing processes to reduce the complexity of integration.
- The method is independent of any specific business system or manufacturing system architecture.

The ANSI/ISA-95 Enterprise/Control System Integration standards define an effective model to meet these goals. The ANSI/ISA-95 standard was developed because of a concern by IT professionals and manufacturing professionals about the problems and difficulties in business to manufacturing integration. As more manufacturing systems are being automated, MES systems installed, and ERP systems coming on-line, there is increasing pressure to integrate these systems.

The group of IT and manufacturing professionals that made up the ISA SP95 committee developing the standard believed that a standard would help resolve the ambiguities and enable the development of robust and safe interfaces. A standard would not only address the important problems raised by manufacturing about maintaining the safety and regulatory compliance of systems, but also address the important problems of information accuracy and timeliness raised by IT professionals. The standard was developed with the goal of internationalization, so that the problems of large multi-national companies and large multi-nation vendors would be addressed.

Several problems have to be addressed for effective integration. One consistent problem is a clear understanding of the boundary of responsibilities between the systems. The manufacturing engineers were concerned about the loss of quality, safety, responsiveness, and reliability if forced to use ERP systems to run their factory equipment. IT professionals were concerned about the quality, reliability, and accuracy of information obtained from the factory floor. Worse yet, vendors were sometimes making exaggerated claims of functionality which confused users and management.

3.1 A set of standards

The ANSI/ISA-95 Enterprise/Control System Integration Standards have become the accepted model for business to manufacturing integration. This standard set contains models and terminology for defining the interfaces between an enterprise's business systems and its manufacturing control systems. Specifically, the standard set provides

1) A common terminology and a consistent set of concepts and models for integrating control systems with enterprise systems (ANSI/ISA-95.00.01 Enterprise/Control System Integration – Part 1: Models and Terminology).

2) A formal definition of the exchanged information in sufficient detail to allow compliant interfaces to be defined (ANSI/ISA-95.00.02 Enterprise/Control System Integration – Part 2: Object Model Attributes).

3) A definition of the activities associated with manufacturing operations (Draft Standard ANSI/ISA-95.00.03 Enterprise/Control System Integration – Part 3: Models of Manufacturing Operations).

3.2 Effects of the standard

There are two primary effects from these standards: a simplification of technological integration, and a simplification of internal company integration.

The technology effect of the ANSI/ISA-95 Enterprise/Control System Integration standard will be a reduction in the time and effort to integrate of business ERP, SCM (Supply Chain Management), and

PLM (Product Lifecycle Management) with MES (Manufacturing Execution Systems). Currently each integration effort is a "one-of-a-kind" effort because of the large number of possible combinations.

For example, the ERP system may be provided by SAP, Oracle, PeopleSoft, Baan, or SCT. The manufacturing system may be provided by Siemens, Rockwell, Honeywell, Invensys, Emerson, or ABB. The PLM solution may be provided by Sequencia, PTC, or MatrixOne. Within a company there may be a single ERP and a single PLM solution, but there are often a large number of different manufacturing solutions. Some companies have multiple ERP systems and manufacturing systems because of mergers and acquisitions, compounding the problem. XML schemas derived from the ISA standard will reduce the technological complexity of integrating these systems together.

The second effect of the standard will be on internal departments within a company and their ability to collaborate and communicate on integration projects. In many companies the manufacturing departments and the IT departments have been operating in separate universes with only occasional interactions. Manufacturing systems have traditionally be designed, installed, and operated by engineers for their own departments, while IT systems have been designed, installed, and operated by IT professionals for other departments (finance, accounting, human resources, etc…). Because of their different backgrounds and focus, these two groups have a difficult time communicating. Previously they did not share much common technology. However, today MES, PLM, SCM and ERP systems are all based on the same commercially available PC based client and Windows or Unix based servers. Modern business systems now also require the same 24x7 (24 hours a day, 7 days a week) uptime and reliability requirement that manufacturing systems always had.

Companies are also now requiring automated, efficient, and accurate information exchanges between their business systems (ERP, SCM and PLM) and their manufacturing systems (MES, DCS and PLC) and they are finding they do not share the same names for items. They sometimes call the different information sets by the same name, and there is little understanding of the meaning or need for exchanged data. The ANSI/ISA-95 standard for business to manufacturing can help departments within companies. It provides a dictionary of terms and a formal model of exchanged information, so that all departments can use the same words and understand the meaning and content of data exchanges.

3.3 Who will benefit

Manufacturing companies will benefit from the standard by having a methodology to integrate their business and manufacturing systems together. Even if it takes time for vendor support of the associated XML schemas, end user companies can use the ANSI/ISA-95 standard today to discover, define, and document integration information. The standards provide a framework for business to manufacturing integration by describing what must be exchanged and when it must be exchanged.

Because of the recent spate of mergers and acquisitions, many factories are now owned by different companies than before. The factories find that they have to provide information and accept information using terminology that they do not understand. Likewise, IT departments are finding that they must integrate with multiple different factories, each having their own different names for items and different structures for the data. The ANSI/ISA-95 standard provides a model for companies to use to communicate internally. This can be done without requiring any software support or systems support because it is just a way to identify and document the elements of that that must be exchanged.

4 AN OVERVIEW OF ANSI/ISA-95

The following sections provide an overview of some of the important aspects covered by the standard.

4.1 A definition of scope of responsibilities

The problems of business to manufacturing integration are primarily internal company issues, but they were compounded by the presence of ERP and MES systems, each with their own internal names and information structures. One of the goals of the standard was to find a way for companies to accurately define the scope of responsibility for these systems and have an accurate and comprehensive definition for the information that had to be exchanged.

There is a simple set of guidelines that define the scope of responsibility for manufacturing operations. These rules help companies determine who has responsibility for specific functions: business functions or manufacturing operations. The guidelines are:

➢ The function is in the scope of manufacturing operations if the function is critical to maintaining regulatory compliance in production operations. This includes such factors as safety, environmental, and CGMP (Current Good Manufacturing Practices) compliance.

➢ The function is in the scope of manufacturing operations if the function is critical to maintaining plant reliability.

➢ The function is in the scope of manufacturing operations if the function is critical to maintaining product quality.

➢ The function is in the scope of manufacturing operations if the function impacts the operation phase of the facility's life, as opposed to design and construction phases of a facility's life.

These guidelines help define the boundary between the Level 3 and Level 4 functions illustrated in Figure 1.

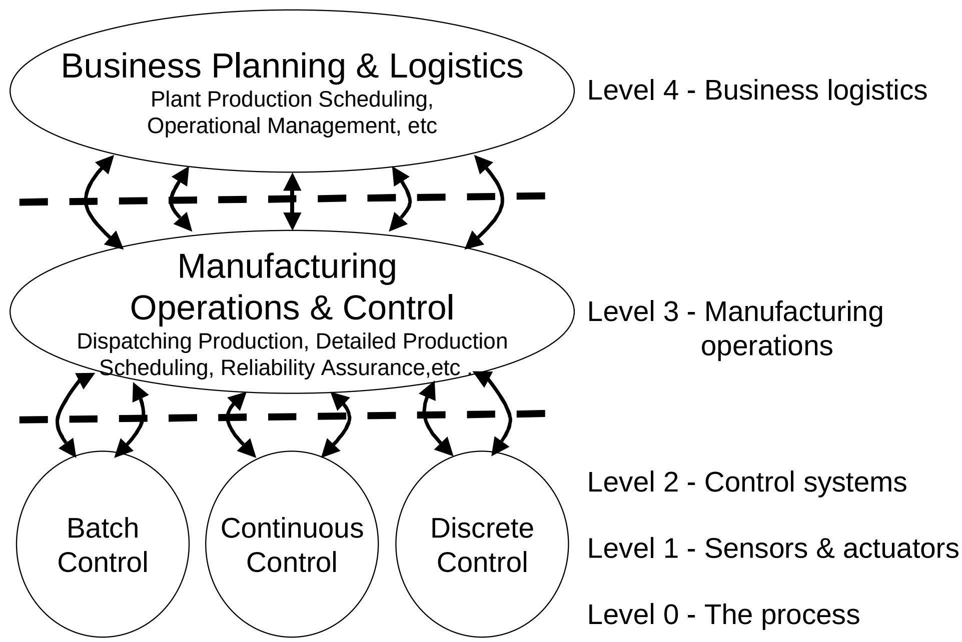

Figure 1 – Hierarchy of activities in a manufacturing enterprise

4.2 Business to manufacturing activities and information flows

A method to help in business to manufacturing integration is to map the company's current business processes into a standard model in order to identify where important activities occur and who has responsibility for them. ISA-95 defines a model for these activities and defines the relationships between the activities in a data flow model. This model identifies specific functions in an enterprise and defines how these functions interact within the manufacturing's control functions. The model structure does not reflect an organizational structure within a company, it represents only an organizational structure of functions. The functions include:

- order processing
- production control
- procurement
- product inventory control
- product shipping administration
- research development & engineering
- production scheduling
- material and energy management
- quality assurance
- product cost accounting
- maintenance management
- marketing and sales

The information detailed in the data flow model includes:

- Actual production from plan
- Incoming order confirmation
- Long term material & energy requirements
- Maintenance responses
- Maintenance technical feedback
- Pack out schedule
- Product and process know how
- Production cost objectives
- Production schedule
- Short term material & energy requirements
- Finished goods inventory
- In-process waiver request
- Maintenance requests
- Maintenance standards and methods
- Material and energy inventory
- Process data
- Production capability
- Production performance and costs
- Quality assurance results
- Standards and customer requirements

4.3 Categories of Information

The information in the data flows listed above was converted into a formal object model. Many of the data flows contain multiple objects, and many objects exist, at least in part, in multiple data flows. A cross reference between the data flows and objects is included in the standard.

Because the object model is very detailed, it is difficult to use it to understand the general collections of information. There are over 50 different objects in 8 separate models defined in the ISA95.01 object model. In order to make the information more understandable, the objects can be collected into general categories: resource definitions, production capabilities, product definition, production performance, and production schedule. These categories of information exchanges are defined using a common definition of personnel, equipment, materials, and segment definitions.

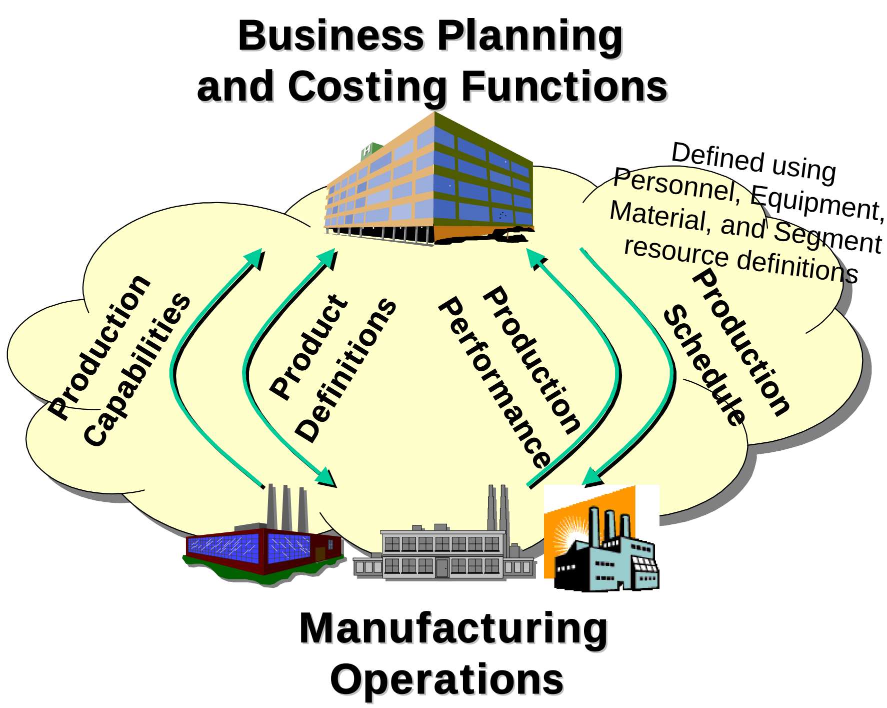

Figure 2 - Exchanged Information Categories

The main categories of information, illustrated in Figure 2, are:

- Resource Definitions – The definition of the personnel, material, and equipment resource definitions used in the other models. This also includes a definition of the segments of production as seen by the business.

- Product Definition Information – This contains information about the resources and segments required to make a product

- Production Capability Information – This contains information about current and future capabilities of production for personnel, equipment, and material. It defines capabilities that are available for production.

- Production Schedule – This is a definition of what products are to be made. It may contain start or completion times, and it may define the resources (personnel, equipment, and material) to be used in production.

- Production Performance – This contains the results of production, as defined by actual personnel, equipment, and material used per production segment, per product or scheduled item.

4.4 Formal model of exchanged information

The following lists define the possible exchanged information, defined as objects. This may not contain all possible exchanged information, but it does cover most of the structured information. Not every application will use all of the objects listed; a company's business requirements will define the information actually exchanged.

Production capability model objects

- Production capability
- Personnel capability
- Personnel capability property
- Equipment capability
- Equipment capability property
- Material capability
- Material capability property

Process segment capability model objects

- Process segment capability
- Segment personnel capability
- Segment personnel capability property
- Segment equipment capability
- Segment equipment capability property
- Segment material capability
- Segment material capability property

Personnel model objects

- Person
- Person property
- Personnel class
- Personnel class property
- Qualification test specification
- Qualification test result

Equipment model objects

- Equipment property
- Equipment class
- Equipment class property
- Equipment capability test specification
- Equipment capability test result
- Maintenance request
- Maintenance work order
- Maintenance response

Material model objects

- Material class
- Material class property
- Material definition
- Material definition property
- Material lot
- Material lot property
- Material sublot
- QA test specification
- QA test result

Process segment model objects

- Process segment
- Personnel segment specification
- Personnel segment property specification
- Equipment segment specification
- Equipment segment property specification
- Material segment specification
- Material segment property specification

Product definition information object models

- Product production rule
- Manufacturing bill
- Product segment
- Product parameter
- Personnel specification
- Personnel property specification
- Equipment specification
- Equipment property specification
- Material specification
- Material property specification

Production schedule model objects

- Production schedule
- Production request
- Segment requirement
- Production parameter
- Personnel requirement
- Personnel requirement property
- Equipment requirement

- Equipment requirement property
- Material produced requirement
- Material produced requirement property
- Material consumed requirement
- Material consumed requirement property
- Consumable expected
- Consumable expected property

Production performance object models

- Production performance
- Production response
- Segment response
- Production data
- Personnel actual
- Personnel actual property
- Equipment actual
- Equipment actual property
- Material produced actual
- Material produced actual property
- Material consumed actual
- Material consumed actual property
- Consumables actual
- Consumables actual property

Part 2 of the ANSI/ISA 95 standard defines attributes for each object. For example, a *material sublot* could contain:

- a unique identification of the *material sublot*,
- the amount of material (count or weight),
- the unit of measure of the material (e.g. parts, kg, tons),
- a location for the material,
- and a status of the sublot material.

4.4 Implementation of the standard

The ISA standard does not directly provide a method for the vendors to exchange information in a standard format. However, the World Batch Forum (www.wbf.org) is developing XML schemas based on the standards. These schema definitions will be freely distributed and cover every object in the standard, such as material classes, material lots, equipment, personnel, product definition, capability definitions, production schedules, and production reports.

Figure 3 illustrates the mapping used to convert the object information to XML schemas. Each dotted collection is an XML schema element.

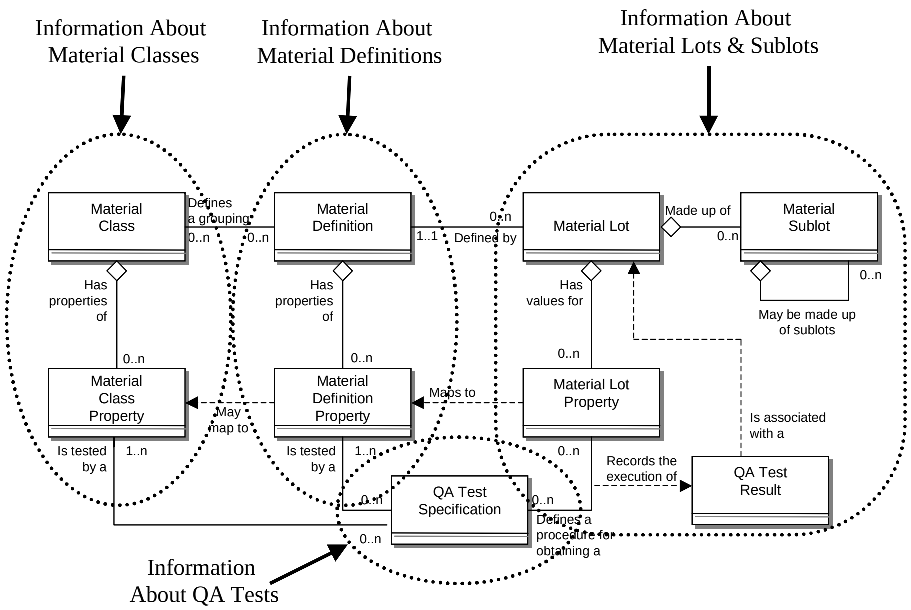

Figure 3 – Example of XML mapping of exchanged objects

There are multiple methods available to exchange XML documents. These range from simple e-mail, FTP transfers, SOAP (Simple Object Application Protocol), or OPC-XML exchange.

5 MODELS OF MANUFACTURING OPERATIONS

Defining the exchanged information is only part of the problem associated with business to manufacturing integration. Manufacturing operations systems must also coordinate and manage real time control systems as well as integrate transaction based business systems. The ISA SP95 committee has started working on Part 3, *Models of Manufacturing Operations*, to address this area. Part 3 will define models for the disparate collection of activities that must occur in manufacturing operations for effective and efficient manufacturing. The goal is to provide manufacturing companies a common model they can use to describe requirements to vendors, and to allow companies to compare alternate architectures and solutions. The committee's plan is to use the MESA and Purdue models of manufacturing operations as a basis for the work, but to have it formal enough to allow vendors to define interoperable products.

Part 3 of the standard defines a model of manufacturing operations, extending the MESA (MES Association) models to include all of the activities involved in manufacturing operations. Even though Part 3 is still in draft form, it is already being used my many control vendors as a blueprint for their MES solutions. The Part 3 model also helps manufacturing professionals understand the activities and functions necessary for correct and complete integration with business logistics, maintenance, and quality systems.

Because Part 3 is still in an early draft form, the names given to activity sets and the complete definitions of the activities are not yet complete. The currently defined activity model is shown in Figure 4.

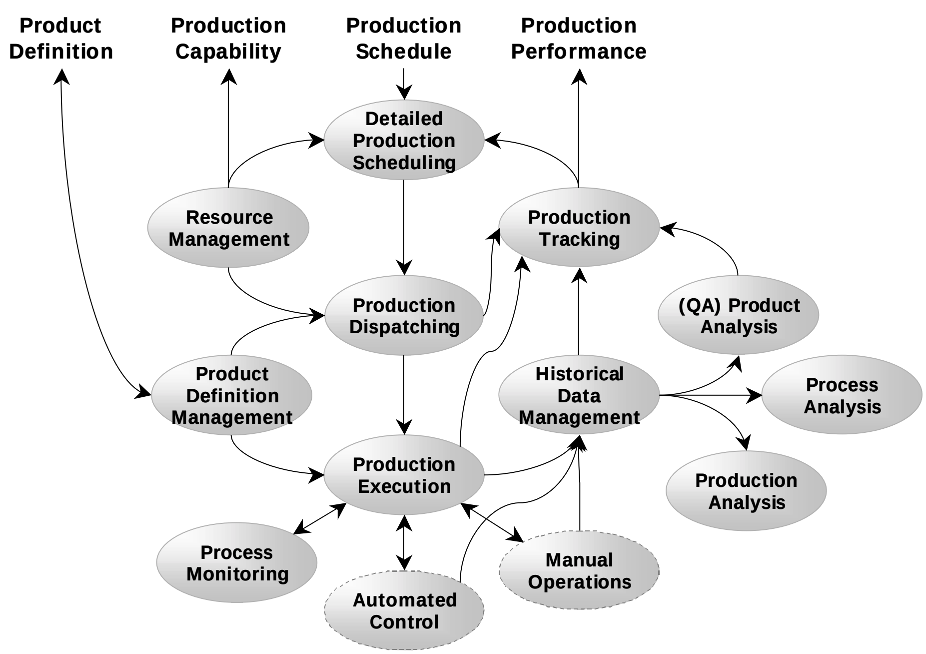

Figure 4 - Activities of Manufacturing Operations

Manufacturing operations includes the following activities for production:

- Production Scheduling - Defines the creation of local production plans for locally managed resources based on business production requirements.
- Resource Management - Defines the managing and allocating locally controlled resources.
- Production Dispatching - Defines dispatching batches to process cells, dispatching machine startup instructions, and inventory control instructions.
- Production Execution - Includes batch execution, manual operations, and setup of automated control.
- Production Tracking - Includes converting equipment information to production information associated with specific production requirements.

- Historical Data Management - Managing continuous information, discrete data, and batch logs for analysis use.
- Product Analysis - Analysis of product quality, such as quality assurance.
- Process Analysis - Analysis of process performance and efficiency.
- Production Analysis - Analysis of production performance and efficiency.
- Process Monitoring - Monitoring the process to ensure safe and efficient operation
- Product Definition Management - Managing the information required to manufacture products
- Automated Control - Some operations of automated control, usually dealing with high level optimization are performed as Level 3 functions.
- Manual Operations - Some manual operations, usually dealing with the dispatching of instructions and logging of responses are performed as Level 3 functions.

Similar activity models are being defined for maintenance and quality operations, as illustrated in Figure 5.

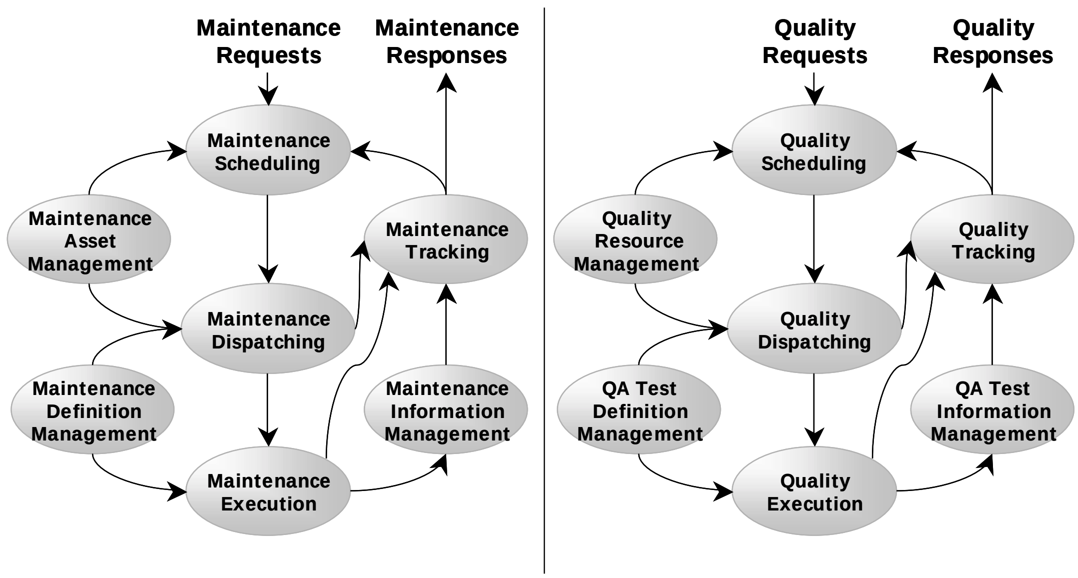

Figure 5 - Maintenance and Quality Manufacturing Activities

6 CURRENT AND FUTURE ACTIVITIES

There is a vote in IEC SC65A to make ANSI/ISA-95.00.01 (Part 1) an IEC standard. There is an equivalent vote underway in ISO TC184 to make it a joint IEC/ISO document. Part 2, which defines the attributes in the object model, and Part 3 will probably be worked on by a Joint Working Group (JTWG 15) between IEC and ISO. This effort will ensure international participation in the standardization effort.

The ISA SP95 committee is continuing work on Part 3 of the standard and has discussed a possible Part 4, to describe the information exchanged between the activities of manufacturing operations. The Part 3 work is expected to take 12 to 18 months before a final committee draft is available.

The World Batch Forum (www.wbf.org) has formed a working group to develop XML schemas for the Part 1 object model, using the Part 2 attributes. This working group has delivered the first draft of the schema definitions and is in the process of testing the schemas, converting them to the new W3C XML schema standard, and generating the documentation of the schemas. This work should be completed by the end of 2001 or in early 2002.

CONCLUSIONS

There are major business benefits that can come from business to manufacturing integration, provided that the reasons for integration are driven defined by business needs. Business to manufacturing integration can support Available To Promise (ATP), Activity Based Costing (ABC), reduction of in-work inventory, and supply chain optimization processes. The ANSI/ISA-95 Enterprise/Control System Integration standards provide a good model to address integration. It provides a framework for companies to apply to internal integration projects, and a set of XML schemas is being developed to assist in technology integration.

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