MAKING SENSE OF THE MESS AT THE MES LAYER

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ABSTRACT

This paper describes a model that aids in understanding the activities that typically occur in the Manufacturing Execution System layer. This model is based on the continuing work of the ANSI/ISA SP95 Enterprise/Control System Integration Committee. The model can be used by manufacturing companies to compare and contrast different MES solutions, determine where they require improvements, and where they have unique requirements. Examples of software available from the control vendors, such as HMI, SCADA, batch execution, recipe management, and data historians, are matched against the functions defined in the model, illustrating where companies have applied software solutions and where they may still need solutions. The model of manufacturing operations also provides a framework for optimizing process and production manufacturing processes.

A FACTORY MODEL FOR A MODEL FACTORY

Figure 1 depicts a model of many of the activities associated with production in most factories. This model is derived from the MESA model and is documents in the draft ANSI/ISA 95 Part 3 Enterprise/Control System Integration standard (1). Each bubble in the figure represents a collection of activities that occur in a production facility as requirements from the business are used to generate plant floor activity. The top four arrows identify information that is usually exchanged with business logistics systems. These are defined in Part 1 and Part 2 of the ISA 95 standard (2). The exchanged information includes:

- A definition of what it takes to make a product, including the *Manufacturing Bill* and routings. (3)

- A definition of the capability and capacities available from production for specified periods of time and locations.

- A production schedule that specifies what products are to be made. A production schedule may include the definition of the personnel, equipment, and material resources to be used in production.

- A report on production performance, defining what was actually produced and what resources were actually used in the production.

The activities defined under the exchanges information are a representation of the activities inside a facility as a schedule is converted into actual production.

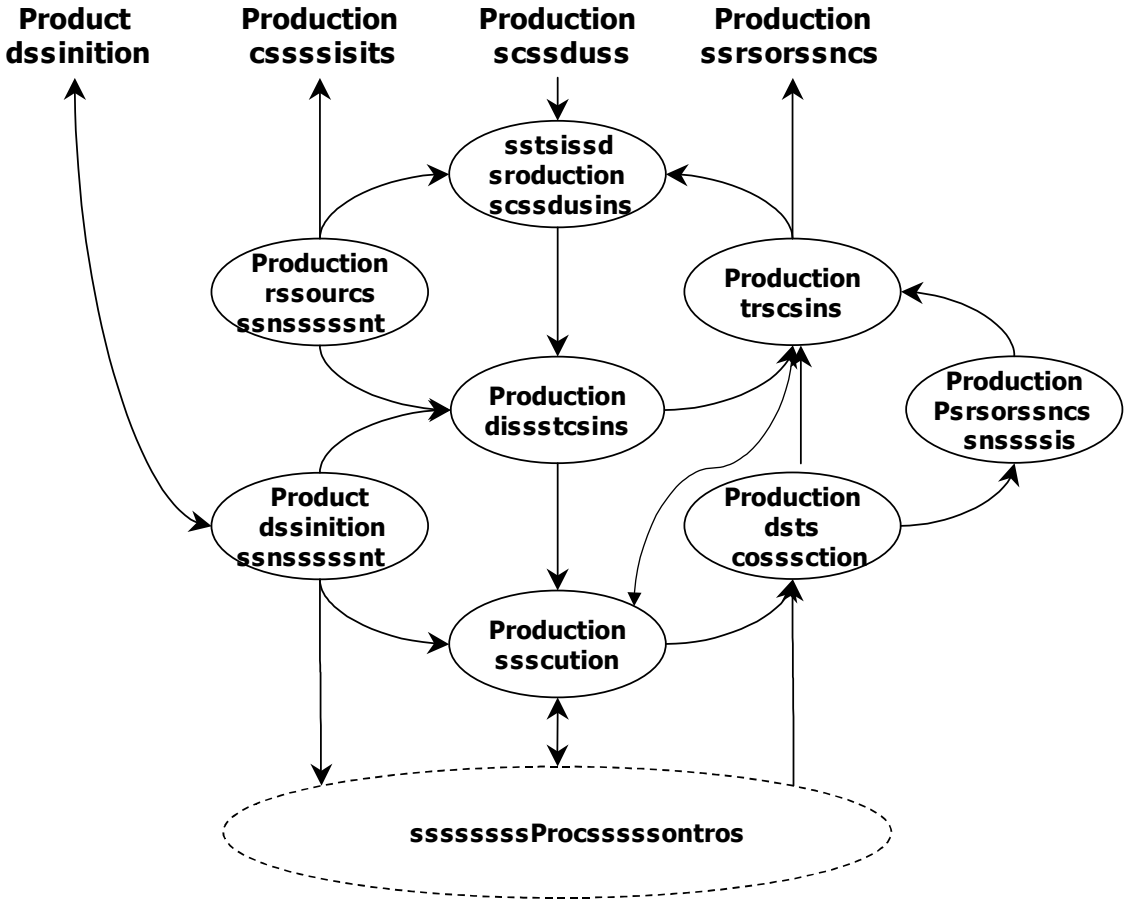

Figure 1 - A Model of Activities in Production

The production activities include:

- Detailed production scheduling - The activities in a facility that take a production schedule and information about local resources and generate a detailed production schedule. This can be an automated process, but in many plants is done manually by expert production planners or

production planning staff. Automated scheduling systems are sometime referred to as plant level advanced planning and optimization systems.

- Production dispatching - Once a detailed production schedule is available that schedule is dispatched to production lines, process cells, and production units. This can take the form of supervisors receiving daily schedules and dispatching work to technicians, or automated systems performing campaign management of batches and production runs. Automated production dispatching is often performed through campaign management systems.

- Production execution - Production execution activities take the dispatched work requests and using manual or automated systems, execute the work. This may take the form of batch execution systems in automated facilities or manual setup for semi-automated and manual facilities.

- Production data collection - Production data collection defines the activities of collecting information from production execution activities and information directly from control equipment and sensors. This information is usually made available to various analysis activities, including product analysis, production analysis, and process analysis. Usually this activity is supported by data historians and automated batch record logging systems.

- Production tracking - The production tracking activities take production execution information and convert it into the production response information required by the rest of the business. This usually involves merging and summarizing information and picking out the small amount of business related data from the massive amounts of production data. Production tracking activities are usually manual collections and summary reports. When automated systems are used they usually link to data historians and batch record logging systems.

- Resource management - The resource management activities monitor the availability of personnel, material, and equipment production resources. This information is used by detailed production scheduling, and summaries are also often used by logistics planning. These activities take into account the current and future predicted availability, using information such as planned maintenance and vacation schedules, in addition to material order status and delivery dates. This activity may also include material reordering functions, such as KANBAN. Resource management is usually a mixed operation, with a mixture of manual work, automation and database management.

- Product definition management - Product definition management includes the activities associated with the management of product definitions. These may be recipes, work instructions, assembly instructions, standard operating procedure, and other information used by production to make or assemble products. These activities are usually supported by CAD systems, PLM (Product Lifecycle Management) systems, and recipe management systems.

- Production performance analysis - The activities associated with the analysis of production, process, and product are defined as production performance analysis. These are usually off-line activities that look for was to improve processes through chemical or physical simulation, product through analysis of good and bad production runs, and production through analysis of

delays and bottlenecks in production. These activities generally are major users of information collected in plant data historians. There are often separate tools for production, process, and product analysis and the tool sets vary based on the type of production (continuous, discrete, or batch).

The above list does not define all of the activities of a production facility. There are also maintenance activities and quality activities, as well as infrastructure activities such as security management, change management, and information management. These activities have additional definitions in the ANSI/ISA-95 Part 3 draft.

A MODEL OF MAINTENANCE ACTIVITIES

Figure 2 defines the model for maintenance activities. It is similar in structure to the production model but if focused on maintenance activities instead of production activities. Maintenance information may be shared between factory maintenance and other business systems including:

- Maintenance definitions - This includes information required for equipment replacement, such as equipment spare parts lists, manpower requirements, and consumable material requirements.

- Maintenance capability - This includes information about the availability or personnel, material, and maintenance equipment for scheduled maintenance activities.

- Maintenance schedule - This defines a list of planned or predictive maintenance activities. One of the main differences between the maintenance model and the production model is that maintenance may be driven by maintenance requests that are generated within manufacturing operations. These can come from operators, technicians, or even directly from equipment. In addition it is common for maintenance schedules to be generated locally within manufacturing operations, but coordinated with delivery schedules managed by the business logistics activities.

- Maintenance performance - This defines the actual personnel, material, and equipment used in the performance of maintenance activities. Maintenance responses usually also go back to the initiating entity as feedback on the actual work done.

The maintenance activities follow the same model as the production activities. There may be a maintenance schedule or maintenance requests that feed into a detailed maintenance scheduling activity. The result is a detailed maintenance schedule that is used to dispatch work, usually in the form of maintenance work orders. There are also activities to collect the results of maintenance work and to correlate those back to activities defined in the maintenance schedule.

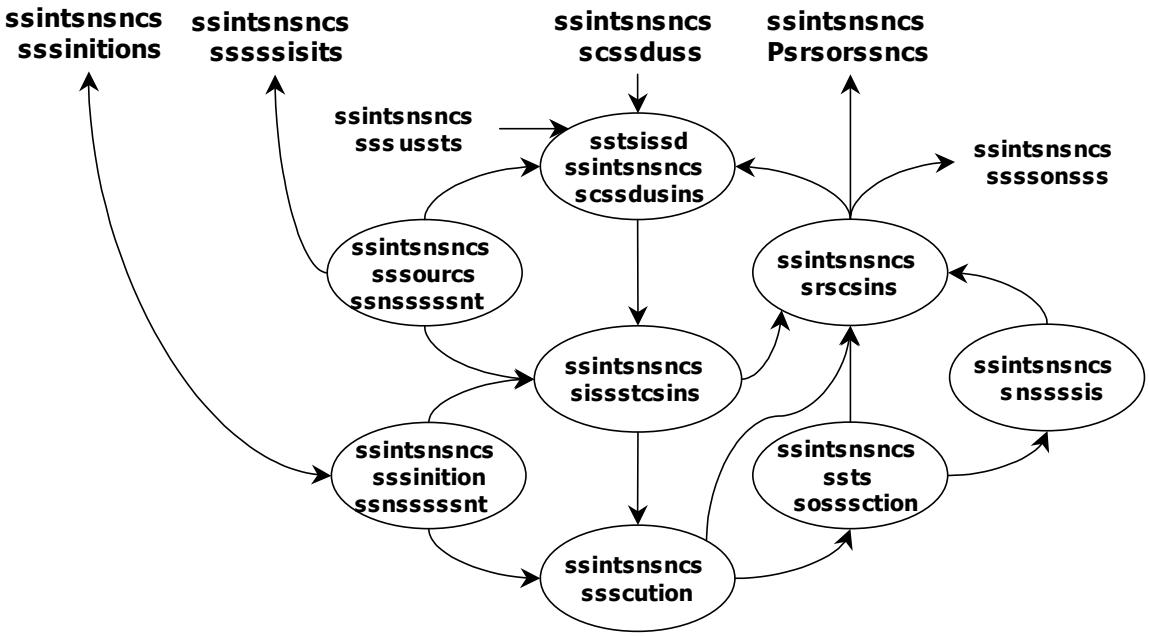

Figure 2 - A Model of Maintenance Activities

The previously mentioned activities are supported by analysis of the maintenance work, maintenance definition management and maintenance resource management. Maintenance analysis is usually done in order to improve maintenance performance or determine predictors of failure. Maintenance definition management involves managing all of the SOPs and maintenance documents associated with maintaining equipment. Maintenance resource management involves keeping track of the personnel, equipment, and materials used in maintenance activities and determining the availability of these resources.

A MODEL OF QUALITY OPERATIONS

The activities of quality operations can also be described in a structure that is very similar to the production and maintenance structures. The model of quality operations is shown in Figure 3. The information elements and activity definition mirror the maintenance definitions, except that they deal with quality functions, usually measurements of quality of products and maintenance of the quality measuring instruments. Many quality operations are driven by quality test requests generated internally by production operations and test results are returned to production.

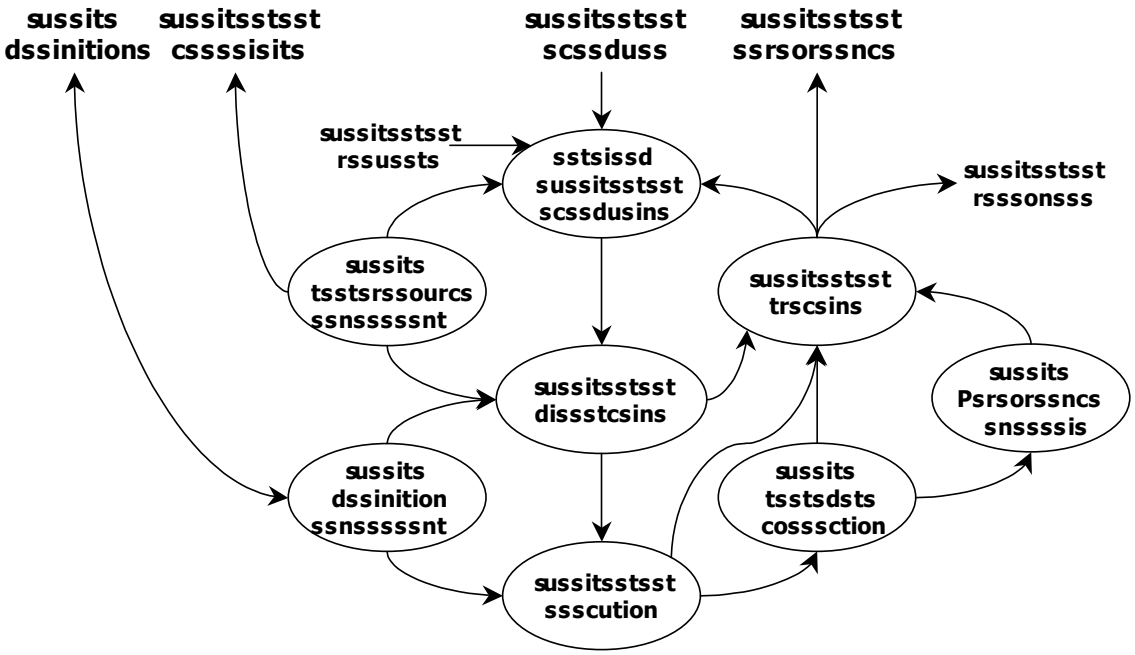

Figure 3 - A Model of Quality Operations

The three models of manufacturing operations are interconnected, requests from one model drive activities in the other models, and responses from one model drive activities in the other models. Most of the interaction is between production and maintenance, and production and quality. However in some systems, such as regulated environments, there is also significant interaction maintenance and quality. Usually there are separate systems for maintenance, quality, and production, but many ERP and control system vendors are starting to provide integrated solutions that address at least some aspects of all three areas.

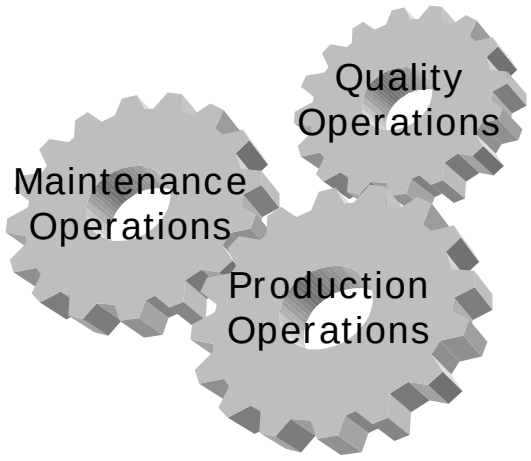

Figure 4 - Interactions between Maintenance, Production, and Quality

WHERE IS MES?

The models shown in Figures 1, 2, and 3 define a large set of activities, only some of which have been traditionally identified with MES (Manufacturing Execution Systems). Unfortunately, the MES model, as originally defined in MESA (the MES Association) white papers (4), does not provide sufficient definition to cover the multitude of different options within production companies. One reason for this is because the boundary between what is done by operations (production, maintenance, and quality) personnel and by back-office personnel is not absolute. There are actually two different boundaries, one that defines the scope of responsibilities, and another related to areas of technical integration.

SCOPE OF RESPONSIBILITY

There are several questions that should be asked to determine the scope of responsibility of production operations. These include:

1. Is the function or activity critical to product quality? If yes, then it should be the responsibility of manufacturing operations.

2. Is the function or activity critical to maintaining regulatory compliance, such as FDA, EPA, USDA, OSHA, cGMP? If yes, then it should be the responsibility of manufacturing operations.

3. Is the function or activity critical to plant safety? If yes, then it should be the responsibility of manufacturing operations.

4. Is the function or activity critical to plant reliability? If yes, then it should be the responsibility of manufacturing operations.

Different environments will give different answers for activities. For example, if quality is only determined at the lowest level activities and not related to scheduling or dispatching, then the MES boundary may be defined by dotted line “A” in Figure 5 below. If collection of production data is required for regulatory compliance, then the boundary may be defined by line “B”. Lines “D” and “E” provide different possible boundaries of responsibility. Line “F” defines the generally defined highest level of operations responsibility for production.

This same partitioning of responsibility can occur in maintenance operations and in quality operations. The decisions on responsibility are based on industry type, regulatory control, and physical properties of production. Unfortunately, there are hundreds of valid combinations of activities.

This complexity is one reason for the inability of the MES layer to have a simple and clean definition. There is no simple and clean definition, because there are so many possible solutions. For example, in a hypothetical regulated drug manufacturing company:

- The detailed production schedule generates schedules for intermediate material production and is critical to product quality.
- The batch record for regulatory compliance is critical to regulatory compliance.
- Material and personnel resource management is critical to regulatory compliance.
- Maintenance of the equipment and of the quality measurement equipment is critical to product quality, plant safety, and regulatory compliance.

In this hypothetical situation all of the activities of production, maintenance, and quality could be under the scope of control of production. In this situation the MES layer would be significant and cover all aspects of production.

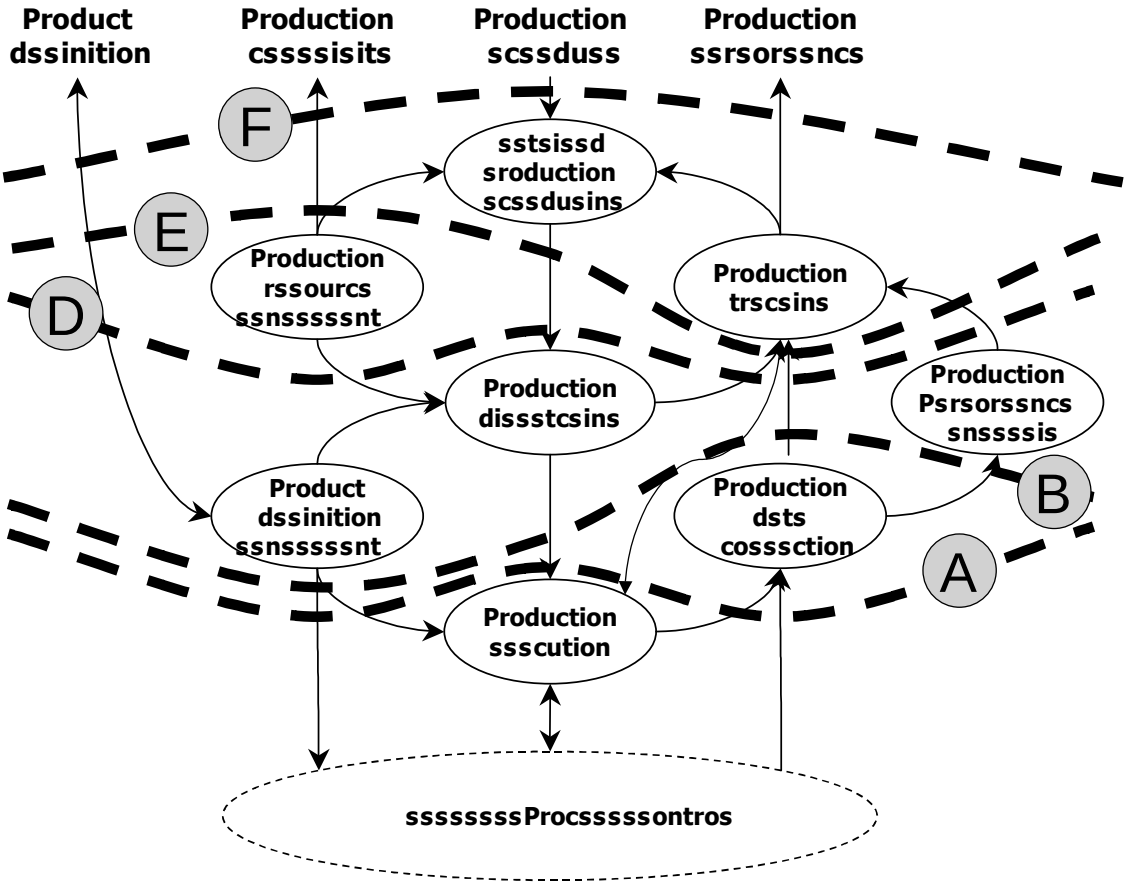

Figure 5 - Different boundaries of responsibility

At the other end of the spectrum of solutions let us assume a hypothetical electronic board assembly facility. In this case:

- Quality is only determined by production execution. The production paths are fixed and production scheduling does not affect quality, safety or compliance.

- Production safety is managed at the Level 2 function through safety interlocks, PC, and PLC programs.

- Maintenance and quality are not critical to product safety or product quality, although they are important for effective and efficient production.

In this situation perhaps only production execution, maintenance execution, and quality execution are within the scope of control of production. In this situation the MES layer would be extremely small and may not be critical.

TECHNICAL INTEGRATION

The situation is even more complicated when technology enters the equation. Many of the functions illustrated in Figures 1, 2, and 3 may be implemented in ERP (Enterprise Resource Planning) systems. Likewise the functions may be implemented by MES systems, or even by some DCS and SCADA control systems. The lines of integration may not be determined by the same rules as the lines of responsibility. The lines of integration are based on technical decisions, including the available of installed systems, the cost of new systems, and integration of existing systems. The line of technical integration may include several systems in the maintenance, quality and production area, and well as several systems in the business logistics area. Figure 6 illustrates one possible line of integration ("X") for a hypothetical company with some maintenance activities and most quality activities supported by ERP systems.

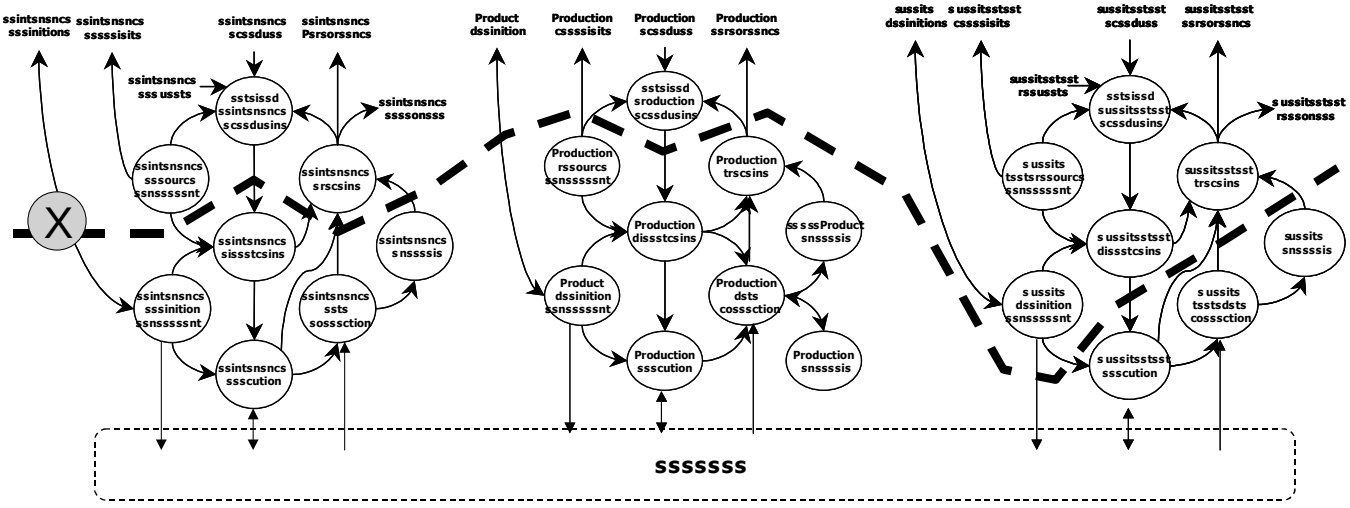

Figure 6 - Lines of Technical Integration

DEFINING SOLUTIONS

The combination of lines of responsibility and lines of technical integration preclude any simple solution to the MES layer. Even companies in the same industry will probably have different solutions. However, the models given here, and defined in the ISA-95 Enterprise/Control System Integration Standard, Part 3 Models of Manufacturing Operations, define a way to approach the problem, segment it, and define solutions. These allow both concise and formal documentation of the lines of responsibility and the lines of technical integration. The two do not need to be the same. There is no problem with manufacturing personnel using ERP systems to automate their processes and activities. For example, an ERP scheduling system may be used by manufacturing operations for detailed production scheduling, detailed maintenance scheduling, and detailed quality scheduling. The important points to remember are:

- There are three main areas to consider in manufacturing operations, maintenance, production, and quality.
- There are two lines of integration to be considered, lines of responsibility and lines of technical integration.
- There are four simple rules for determining if an activity should be under the scope of control of manufacturing operations.
- There is no single answer to the MES layer, the determination of what activities are covered and where the system must integrate with business logistics may be different for every company. One size will not fit all situations.

REFERENCES

1 - ANS/ISA-95.00.03, Enterprise-Control System Integration – Part 3: Models of Manufacturing Operations, Draft 7, Available from The Instrumentation, Systems and Automation Society (ISA), RTP North Carolina, USA

2 - ANS/ISA-95.00.01-2000, Enterprise-Control System Integration – Part 1: Models and Terminology, Part 2: Object Model Attributes, Available from The Instrumentation, Systems and Automation Society (ISA), RTP North Carolina, USA

3 - Cox III, James F., Blackstone Jr, John H., APICS Dictionary Ninth Edition, APICS - Falls Church VA, ISBN 1-55822-162-X

4 - MESA International, MES Functionalities and MRP to MES Data Flow Possibilities - *White Paper Number 2 (1994)*