INTRODUCTION TO MANUFACTURING EXECUTION SYSTEMS

MES CONFERENCE & EXPOSITION

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About the Author

Mr. Michael McClellan is president of MES Solutions Incorporated, a company specializing in consulting services aiding clients in the design and implementation of Manufacturing Execution Systems. Prior to his current position Mr. McClellan was President of a major supplier of material management and control systems. Before that he was a founder and President of Integrated Production Systems, a company that pioneered the development and implementation of computer systems for production execution. While at Integrated Production Systems he published two papers and numerous articles on the subject of applying computer systems in manufacturing operations and managed the company that developed and installed systems for major clients.

Prior to forming Integrated Production Systems Mr. McClellan held officer level management positions in companies providing equipment and control systems for production and material management.

In addition to his work experience Mr. McClellan is a member of the Manufacturing Execution Systems Association (MESA International), American Production and Inventory Control Society (CPIM) and the Society of Manufacturing Engineers. He is a frequent speaker on MES, holds one patent, and is the author of the recently published book, *Applying Manufacturing Execution Systems*.

Mr. McClellan is interested in any comments and ideas regarding MES and can be reached by telephone at 541 548 6690 or Fax at 541 548 6674 or by mail at P.O. Box 2148, Terrebonne, Oregon 97760.

Bridging the Gap

Applying information technology to assist in the execution of production, through on-line management of the activities at the plant floor, has been a rapidly growing trend for a number of years. Planning systems have been applied under a variety of titles, including Material Requirements Planning (MRP), Manufacturing Resources Planning (MRPII), Enterprise Requirements Planning (ERP), and Manufacturing Control Systems (MCS). Also in place for many years are modern control systems that manage or control a machine's functions such as PLCs used to run machine tools.

The MES system bridges the gap between the planning system and the controlling system using on-line information to manage the current application of manufacturing resources: people, equipment and inventory.

With direct electronic connections to the planning system and the equipment control systems, the MES is the hub that collects and provides information and direction within the production activities. To support on-line management decisions the MES usually includes direct connection to functions such as SPC, Time & Attendance, Product Data Management, Maintenance Management, and any other similar tool.

A General Overview

Technology Evolves

The idea of using computers to manage manufacturing activities is not new. The concepts that allowed the development of Materials Requirements Planning evolved from computer usage primarily within the accounting departments (the main users of early computers) and were extensions of tools used for cost accounting and inventory measurement. Even the systems used by manufacturing have been oriented toward accounting and finance. This appears to be part of the reason for the distance between many manufacturing professionals and true computer implementation on the manufacturing floor.

Many legitimate complaints are often stated about the computer systems used in manufacturing. For example:

- The information is too old.
- I don't have time to read such a big report.
- How much of this information applies to me.
- This information applies to accounting or MIS, not to manufacturing.
- All this is history. I need to make decisions based on what is happening now.

A new idea is evolving. In recent years a concept with many versions has been developed for manufacturing managers—a real tool that helps manage the manufacturing floor, functions, resources, and inventory and gives accounting and MIS all the information they require.

The best part is this idea is being built around the manufacturing world and requires no advanced knowledge of computers. In most cases these systems run on smaller local computers and are fairly simple to use.

Manufacturing Execution Systems

This concept has been around long enough to have a name: Manufacturing Execution Systems (MES).

As the name implies, MES is more than a planning tool like ERP or MRPII. MES is an on-line extension of the planning system with an emphasis on execution or carrying out the plan.

Execution means:

- Making products.
- Making and measuring parts.
- Turning machines on and off.
- Moving inventory to and from WorkStations.

- Changing order priorities.
- Assigning and reassigning personnel.
- Assigning and reassigning inventory.
- Setting and reading measuring controls.
- Changing order priorities.
- Scheduling and rescheduling equipment.

Manufacturing Execution Tool

The MES is a manufacturing tool designed and built for manufacturing. Most manufacturing companies use a planning process (MRPII/ERP or equivalent) to determine what products are to be manufactured. Once that plan has been developed, there must be a translation of the plan that deals with real resources that are currently available. What is necessary is a method to take input from the planning system and translate that plan into a language that fits the plant floor and the resources required to execute the plan—a major role for the MES.

What MES Can Do For You

MESA International has conducted studies of companies using MES and offers the following benefits as reported by system users:

- Reduces manufacturing cycle time.
- Reduces work-in-process inventory.
- Reduces paperwork between shifts.
- Eliminates lost paperwork/blueprints.
- Improves customer service.
- Reduces or eliminates data entry time.
- Reduces lead times.
- Improves product quality.
- Empowers plant operations people.
- Responds to unanticipated events.

The potential gain by implementing MES addresses the need for immediate, current, on-line information that allows users or the MES computer system to make the best informed decisions regarding the application of inventory, plant resources, and people. Some examples include:

1. Engineering wants to locate all current work orders for a given product to determine the effect of an immediate engineering change order.
2. Some purchased material that is specific to a given customer's order currently in process has arrived as a partial shipment, 72% complete. Where is the order and what is the appropriate response?
3. A customer requires specific operator information including operator, date, and ambient conditions to be supplied with each item produced.
4. A process critical to production needs preventative maintenance. How are the current orders to be scheduled?
5. The president of a high-volume customer has just called and needs to know by tomorrow if he can double the quantity on the current order in house without affecting the delivery schedule.
6. There are 26 work orders totaling 443 hours of work for a specific routing location. What is the optimum sequence for these work orders and what factors should be considered?
7. A new quality assurance system has been installed that can receive and analyze data from the plant floor and provide current on-line results to the workstation operator.
8. Operator time is charged to each order and collected as the order passes through production through the use of a time card data collection system using bar code readers and menus.
9. Inventory can be retrieved from storage and sent to a specific workstation matching the production schedule.
10. The shift supervisor is considering replacing a part on a production machine and needs to know if the part is in stock and how long the maintenance work will take.
11. Information regarding inbound inventory can be gained by a through a communication link with the vendor's MES computer.
12. A sales representative is at a customer's office and needs to know where their order is in the production process.

CORE FUNCTIONS

The following is an overview of the core functions of the MES:

Planning System Interface

The MES should be directly coupled to the planning system to accept work orders and all other input and to provide upload information as necessary. The communications should be two way so the MES can keep the planning system properly informed about plant activities such as labor data, inventory changes, and work order progress. Other methods of data entry and reporting can easily be accommodated, and in some cases, such as more continuous process, production orders may not be used at all.

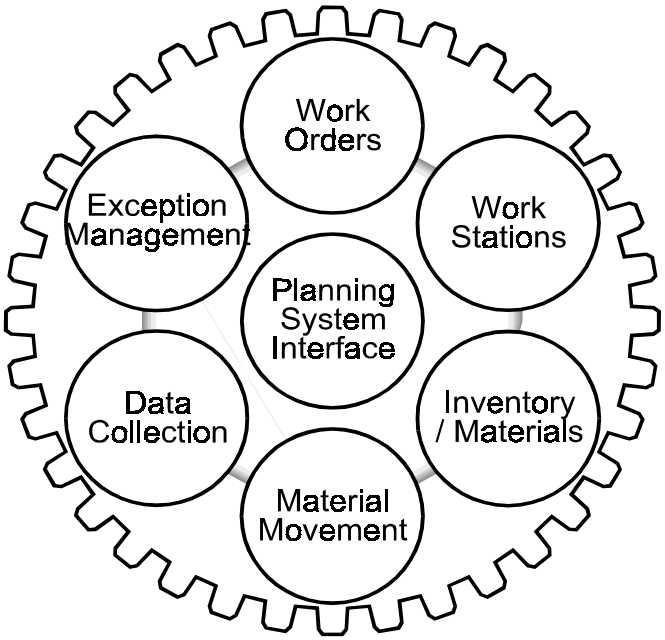
Work Orders

The MES accepts the Work Order through automatic or manual entry. It manages changes on orders, establishes and changes schedules, and maintains a prioritized sequenced plan.

Releasing orders to production and establishing a current order priority list based on your sequencing rules is a normal part of MES. Frequently changes must be made to released orders. Within MES, order modifications such as these examples can be done easily:

- Enter schedule changes.
- Mark for material shortage.
- Enter quantity changes.
- Place on hold.
- Split orders or combine orders.

The Work Order management function maintains a constant real time view of the work orders in the current backlog and the status of each order.



Work Stations

This part of the system is responsible for implementing the direction of the Work Order plan and the logical configuration of the WorkStations. The planning, scheduling, and loading of each operational Work Station is done here, providing the current and total shop load by operation using routing data and time standards. Based on this plan, the system will request and manage delivery of inventory, tooling, and data in response to the Bill of Material requirements and will issue and execute commands to move the required items to the planned WorkStation. The MES can and should include the direct control interface and connection with each WorkStation.

Inventory Tracking and Management

While the planning system has the aggregate data on inventory, the detail can easily reside at the local level—the MES. "Dock To Stock" operations are accomplished here with regular updates to the planning system. A current map of all inventory and storage locations, including WIP, is maintained.

Material Movement

Another major area of MES system contribution is the movement of inventory or information to the needed location on the plant floor. This portion of the system controls material movement in the plant, in manual or automatic systems, by issuing requests for a manual move (printing move tickets) or issuing commands to material handling system control PLCs, such as ASRS, AGVS, conveyor systems, carrousels, robots, etc. The commands can be as simple as "move this item from this location to that location."

Data Collection

This part of the MES system is the eyes and ears for management and gathers information so the system can remain current. Through various kinds of sensing devices and control interfaces, data from the floor operations can be collected, collated, and dispersed on whatever basis is desired. This is the primary method for all personnel to communicate with the MES, either through information input/output by system operators or recognition of events electronically. Direct connections with PLCs to download and/or collect information are also part of this function area.

Exception Management

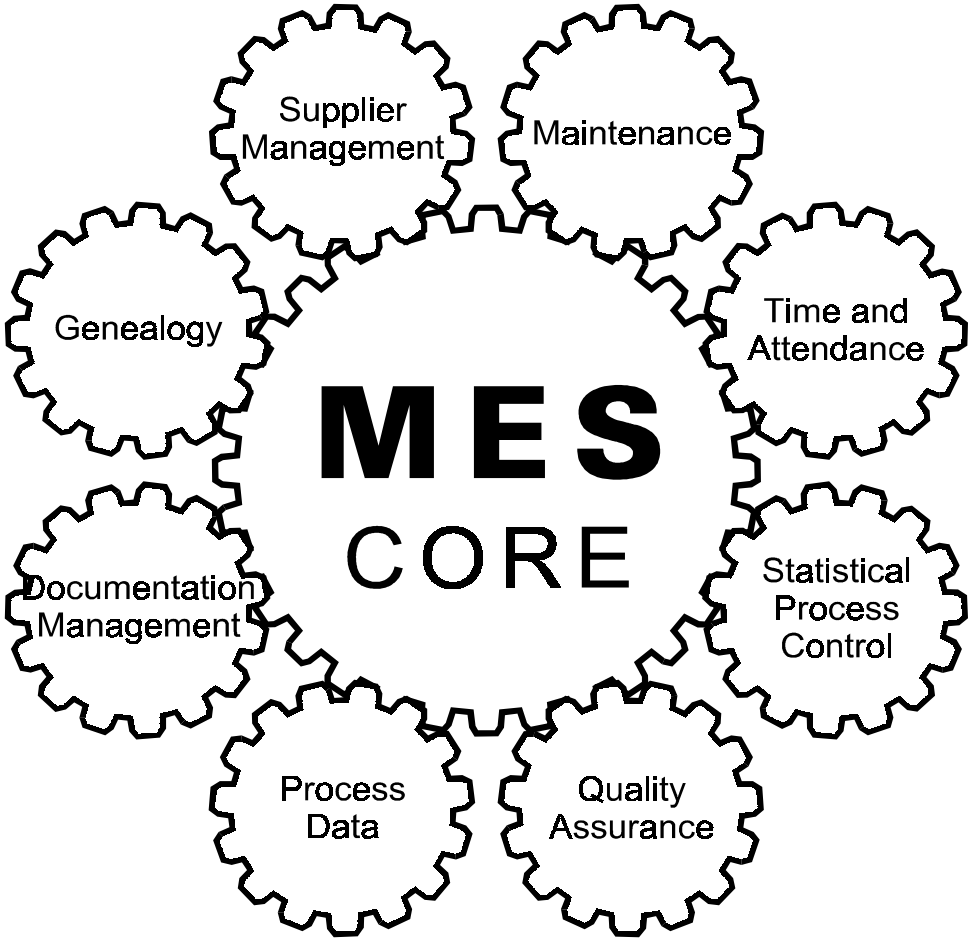
The most custom portion of the MES is addressing how a company responds to plan exceptions. What happens when a WorkStation is suddenly down, or when material is not available, or when a Work Order becomes "hot"? The MES should be able to take these changes in stride and respond with alternative actions.

Our process began with a planned or sequenced list of Work Orders, methods to schedule those Work Orders into Work Stations, control of inventory assignment, and management of material movement. Along with data collection to keep the system current and a way to handle exceptions, we have the ability to execute the manufacturing plan—truly a **Manufacturing Execution System**.

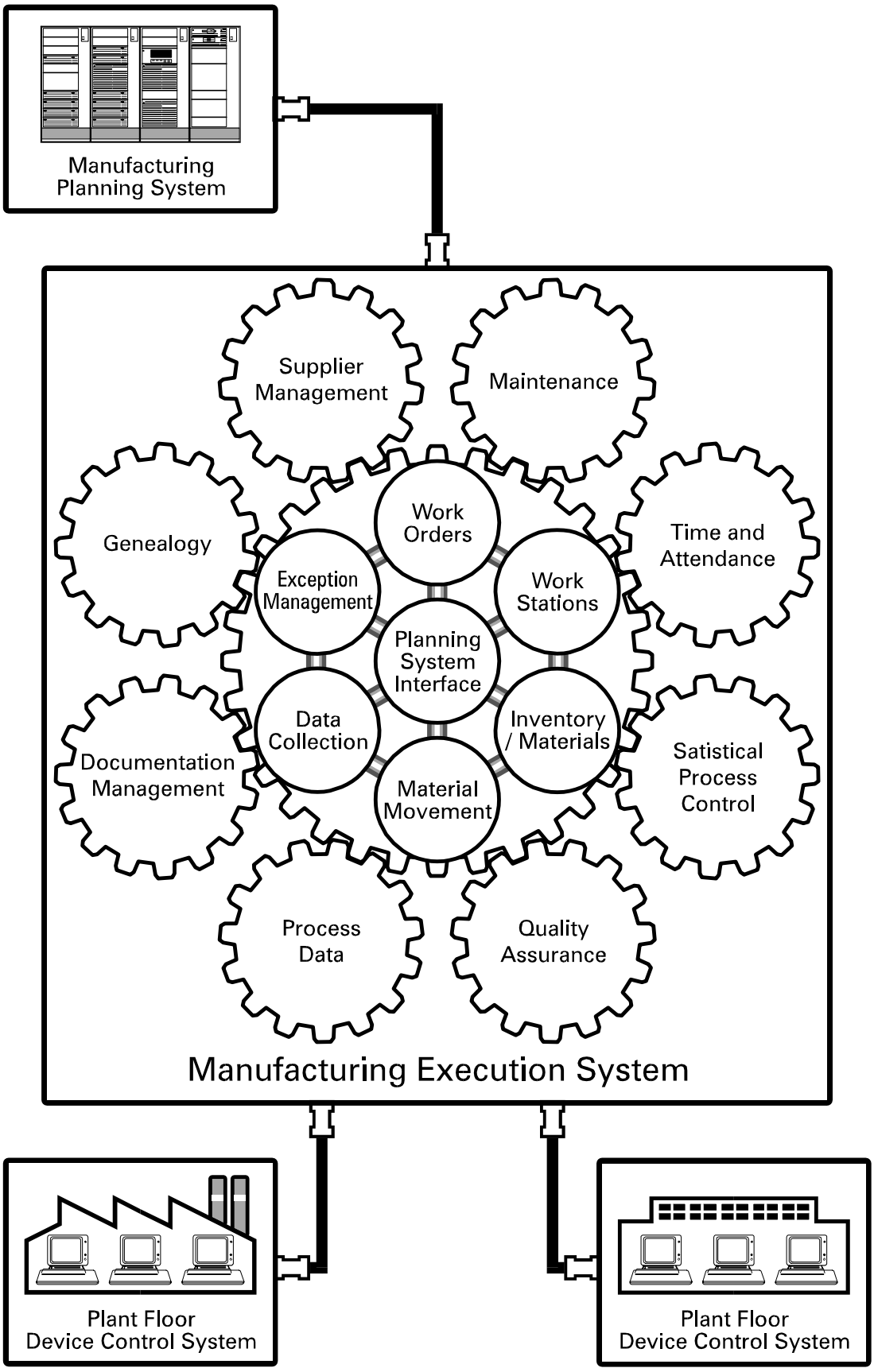
Support Functions

Other components of Manufacturing Execution Systems act as Support functions. These are programs or software packages that support manufacturing but are not part of the planning process or the device control system. The most popular applications are listed here, but there are others, and more will be developed in the future.

- Statistical Process Control
- Maintenance Management
- Time and Attendance
- Product Data Management
- Process Data/Performance Analysis
- Supplier Management
- Genealogy/Product Traceability
- Laboratory Information Management
- Quality Assurance



Manufacturing Execution System



Agile Manufacturing

Agile Manufacturing is the ability to efficiently and competitively make "one of many" instead of "many of one." The idea is similar to "a lot size of one" with a greater intensity and focus on timeliness, allowing insertion of the "one" into the production plan as necessary to meet customer requirements—usually sooner rather than later.

This can be effective only with a detailed understanding of the current situation and a control system that allows immediate change of resource assignment. If your largest customer requires a change to an order, do you know the effect and can you respond to the request? With a properly designed MES system, the information necessary to view all the options is readily available.

Application Examples

Planning System Data Exchange

A major role of the MES is to collect, collate, and upload data to the planning level system. It would be difficult to describe each possible scenario since there are many existing and available varieties of planning system installations and products. Each system interface must stand on its own depending on the input and output requirements.

These requirements can best be established in a meeting with the planning system vendor, the users, and the MES provider. This meeting should be held early in the system design process to determine the feasibility of the interface.

Receiving Within MES

Receiving can be treated as another group of work stations with processing routings established by reading the incoming bar code label (either PO number or part number). This displays a screen to the receiving personnel for appropriate data entry and establishes the routing for this specific receipt.

At this point, the material begins its tracking within the inventory function and is directed through quality assurance processing steps. The material may be sent to a buffer storage area for later retrieval and assignment to a specific processing work station or sent immediately to the appropriate work station. Following the incoming processing steps, the material can be put into inventory for assignment to production orders or, upon failure to pass incoming processing, is sent to the appropriate Work Station for disposition. Disposition decisions are made and executed with status inputs to the MES and uploaded to the purchasing and inventory modules of the planning system.

Timed Operation Routing Step

The MES can automatically perform timed operations as part of the routing used in WorkStation scheduling. An example of a timed operation might be a "burn in" operation where the product is removed from a Work Station, sent to storage, and retrieved automatically after the timed function is complete.

Work Scheduling or Sequencing

A very obvious question that should be asked frequently in manufacturing management is "What is the schedule of work to be performed?" Though it may seem obvious or intuitive, the area of schedule development probably offers the best opportunity for improving the resource management process. The issue here is not to determine production quantities (presumably, that was determined by the planning system), but rather how to rank a given list of tasks based on the resources (people, equipment, and inventory) currently available.

System Requirements

MES projects have developed on a somewhat piecemeal basis, but as the concept grows, the need for broader system design considerations for all software and hardware is increasingly obvious. Major system revisions as well as all new systems should be designed to include:

Full Integration

All systems must be able to exchange information and not be excluded from the overall system process. The concept of the information warehouse where each computerized activity draws from and delivers data to the system is becoming increasingly important.

Scalability To Future Needs

The design of the software and hardware must allow upward scalability to meet the increasing needs of your company as growth and change occurs.

Compatibility With Existing Systems

Ideally, an MES system should be incorporated into the existing systems. However, this may not be economically feasible with systems using older software.

Broad System Access

Information is the tool that gives users access to what is going on. It will be increasingly more important to broaden the audience of information users. Do not be overly restrictive.

Security

While broad access is a cornerstone, so too is the requirement of adequate security, primarily to ensure data integrity

The Ability To Upgrade Hardware

The system must allow hardware and technology changes to be made easily without disruption.

Easily Added Functionality Changes

New and better ideas will be obvious after the MES is in operation. As continuous improvement opportunities present themselves, the system must incorporate these changes with little cost or inconvenience.

System Risk

Some MES projects fail—not because of computer or software malfunction but most frequently, from poor definition. Other reasons include:

- Extensive custom software
- Customer delays and changes.
- Too much reliance on the vendor.
- Choice of product or product vendor did not fit the needs.

Be Risk Averse

We recommend that buyers adopt a strategy of being ***risk averse***—that is to avoid the risk of system failure.

Accept Responsibility For Your System

The most important aspect of being ***risk averse*** is to accept system responsibility—define in detail what you want the system to do. This requires more up-front work but the payoff will be very rewarding.

As you define what you want the system to do for you, you must think through how you want to manage your business—a responsibility that should not be transferred to a vendor.

System Requirements Definition and Functional Design Specification

The System Requirements Definition should provide the definition and analysis of the current problems and opportunities, the objectives and goals of the system, and the expected results of the project.

- Identify the fundamental problem or problems the system is to address (the "as is").
- List specific needs the solution must satisfy related to functions and tasks (the "to be").
- Describe the physical system environment, the expected users and their computer skill level.
- Indicate any hardware and software preferences or needs.
- Describe the minimal quality, performance, security, and support requirements.
- Describe any compatibility and legacy system migration needs.
- Describe the system support requirements.

Taking the requirements on step further, the Functional Design Specification (usually done by the vendor and reviewed by the buyer) describes in detail what the system will look like to the user. This includes each screen, data field, and key stroke definition along with all interfaces to external participants or data points.

- Identify all data input and output points with the data characteristics.
- Layout each screen or man/machine interface with exact definitions for each keystroke.
- Identify and describe any and all expert rules.

This effort may seem exhaustive and too detailed but these definitions and decisions must be made either by the vendor or by you, the buyer. If you do not understand, in detail how the system will function you will have left important decisions on how your company is run up to the vendor.

Can you take that risk?

A New Approach

This paper has been presented at earlier forums and is a shortened version of the book, *Applying Manufacturing Execution Systems*. The information presented in both of these has been a useful definition of what a using company might envision their functional system requirements to be. There have been few, if any, vendors that could provide a complete set of the listed functions as outlined and even fewer that could accomplish a system with fully or even partially integrated functions. This is changing.

There is a new approach to the manufacturing environment that provides much easier integration between applications and takes into account the realization that existing plant methods and systems cannot be simply discarded and replaced. This view includes a fundamental change to the historical hierarchy of the three tiered systems by consolidating the controls level with the execution level.

It has been long established that planning systems (ERP) fall in the category of decision support systems while plant environment applications are most often on-line transaction processing systems. This natural categorization provides a simple dividing line (never an absolute) between these systems and might even suggest that controls and execution could be combined, which is what is beginning to occur in the market.

ERP vendors have long taken a system approach that centers on an overall framework that integrates application modules to provide a global answer to those issues such as financial, personnel, and planning, etc. This idea has now come to the area of plant applications even while recognizing the differences of system implementations where an open environment is an absolute must. This is where legacy systems and new applications from one or more vendors must be easily integrated into a holistic manufacturing system. This new approach of combining the controls system functionality with the execution system applications is often referred to as the Enterprise Production System.

This change has been in process for some time but has been accelerating with the firm establishment of software standards in manufacturing such as Microsoft DNA. With systems following common standards, the ability to integrate functions has become much easier, less costly, and faster to implement**. Stay tuned. The plant system world is going to get a lot more interesting and more satisfying very fast.**

Portions of this paper were presented at National Manufacturing Week, Chicago, Illinois, and are reissued with their permission.

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