Controls Definition & MES to Controls Data Flow Possibilities

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Purpose
This paper is designed to create a functional architecture for the data flow possibilities and composition of the MES to Controls layers in an overall integrated Enterprise.

Control System Definition
A Control System is defined as being “responsible for measurement, monitoring, and manipulation of production, people, products, and processes” within the environs of the process or shop floor. It is within this context that the functionality of this paper resides.

White Paper Number 2, “MRP to MES Data Flow Possibilities” defined the communications, data types, and data flow between the Office and Factory Information Systems. That environment is transaction-based; data is exchanged in direct response to scheduling, routing, or production planning requirements. Contrast that with Controls: decisions are made in seconds, or fractions thereof, in response to process, or discrete operations and needs. This difference of a real-time environment effects most transactions and executions that occur in the Controls layer.

Ultimately, this White Paper is meant to:
• Develop an original MESA Controls Functionality Overview
• Promote the MESA model for “MES In An Enterprise” diagram (page 5).
• Advance the state of work to adequately educate potential users of MES within the discrete, JIT / repetitive, make-to-order, job shop, batch process and hybrid industries.

Background
 Manufacturing Execution Systems (MES), as defined by AMR, are “information systems that reside on the plant floor, between the planning systems in offices and direct industrial controls at the process itself.”

There are three layers within AMR’s MES Integrated Enterprise model:
• Planning: the front office/accounting/financial systems
• Execution: the factory level coordinating/trending/tracking systems
• Control: the factory floor/process control systems.

MES is designed to fulfill the needs of the broad manufacturing enterprise, by coupling front office accounting with the factory supervisory control systems and products. The overlying benefit of MES is to not only link but closely tie the outputs of these three layers of information systems—those residing in the Planning Functions, such as MRP II, Execution Functions, such as
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The Controls Layer: Controls Definition & MES to Controls Data Flow Possibilities

supervisory control software or Quality Control, with the Control systems that create the data utilized, so that the Enterprise has full access to the separate databases of information that exist within the organization.

Key functions that MES systems provide include:

- Scheduling
- Resource Allocation
- Quality Management
- Process Management
- Dispatching
- Maintenance Management
- Document Control
- Product Historian
- Data Acquisition
- Operations Analysis
- Labor Management

These functions operate to “translate” the real-time data occurring on the factory floor into information that is useful from a process control/management standpoint. This then will ripple into other adjacent processes such as labor, equipment, and materials management; product tracking; and supportive systems such as Quality, LIMS, and Document Management.

The Control Systems’ focus is on the process or operation itself — sequencing and manipulating the process to assure that tolerances are kept within defined limits, that material flow is maintained, and that all of the people, equipment, and resources involved within the process are fully utilized.

Interaction between the Control and MES layers is dynamic; control information/status can be accessed as it is created, satisfying SPC and SQC needs; or it can be batched for later observation, meeting labor tracking or maintenance needs.

Likewise, the Control layer can query the MES (Execution) layer for status changes, recipe updates, or other operating instructions. This results in support of the functionalities of the MES layer — resource allocation, operations scheduling, production dispatching — and the supply of real-time data from the outputs of the Control layer.

The Control layer concerns inputs and outputs, or status points, of the process. These points can be relayed as they occur, trended as part of the functionality within the controls themselves, or can be stored in databases for analysis, all to assure that the product or process is progressing within defined limits.

It is important to note that MES is not concerned just with continuous processes; critical Control layer information exists within discrete manufacturing processes, such as those found within the automotive or electronics industries. In these instances, rather than being concerned with setpoints, values and material flow, MES would look at the material tracking, routing, yields, and the associated quality parameters to assure that utilization of people, equipment and materials are optimized.

The Control layer is the final layer in the office-to-factory-floor paradigm. Information needs from the office—from WIP to final package counts to shipping information — are all based upon available information from the Control layer, and require only the correct software/hardware package to access the data that already exists there in various form factors.

Implementing MES: Data Flow Possibilities

So how would MES function in a typical factory? Many of the components described within the MES to Controls layer probably already exist. Look at the following diagram (page 4) describing the operations, interactions, and data flow between the Execution and Controls layers:

The Execution layer is represented by those functions that are in charge of the overall flow of the product and/or process, such as those found in “SCADA” (Supervisory Control and Data Acquisition) systems. A SCADA...
system would control the execution of a specific recipe at a specification operation that the Execution system passed to it. Central repositories of data are collected from various locations within the factory, rather than being localized within a particular area. The specific performance of a piece of equipment, or an operator, may not be as important to the Execution layer as it would to a control operator. The results from these discrete operations would be blended into the process control data, and then those results would be communicated to the Execution systems.

The Execution layer, then, **downloads Instructions (for a specific recipe) to the Control layer.** These instructions supply direction to the people and machines required to carry out the manufacturing operation.

It is the function of the Controls people and machines to then monitor and control their own operations, to assure that the outputs are in compliance with the requirements set forth from the Execution layer. This monitoring and control can include separate software and hardware products for quality, process control, data acquisition, safety and maintenance. **Drill-down inquiries, or status indicators,** from the Execution layer can spontaneously access information created on an as-needed basis for process control.

**There are also bilateral inquiries that can emerge from either layer:** these inquiries can be used to measure progress-to-plan; to communicate unscheduled changes; or to announce alarms, events or changes that have occurred.

The Controls function is the use all of the equipment on the factory floor— hardware, software, and people, in a manner consistent with the goal of producing a product or process that falls within the parameters set forth by the corporation. M E S serves as a two-way window into the manufacturing process, integrating and facilitating key

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The diagram below depicts the data and information flow that occurs once M E S is implemented within an organization. Notice the information that is accessible and the various interactions that occur.

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**MES to Controls Data Flow Possibilities**

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### Execution

- **MES**
  - Resource Alloc./Status
  - Operations Scheduling
  - Production Dispatching
  - Document Control
  - Data Collection/Acquist.
  - Labor Management
  - WIP Status/Traceability
  - Quality Management
  - Performance Analysis
  - Process Management
  - Product Tracking & Genealogy
  - Maintenance Management

- **Focus:** Product
- **Decision Location:** Factory/Plant

### Control

- Monitoring & Sensing
  - Process
  - Equipment
  - Environment
  - Labor
  - Material

- Control
  - Machine Control
  - Regulatory Control
  - Realtime QC
  - Advanced Process Controls

- Operations
  - Process Sequencing
  - Machine & Process Instructions
  - Labor Instructions
  - Human Machine Interfacing
  - Safety
  - Maintenance

- **Focus:** Process
- **Decision Location:** Shop Floor/Plant Floor
information flow and commands between Controls and business planning systems for total resource and enterprise management. MES can be the key implementing cornerstone in achieving an ERP/MES/Control integrated Enterprise of tomorrow.

**MES Within an Enterprise - Data Flow Diagram**

From the left (below) you can see the MRP system. They normally do not work in “real-time,” but rather in a batching mode; that is the 100x time factor. The MRP system notes product usages, customer orders, and materials requirements, and sends requests to the Execution (MES) layer to build more product to fulfill these needs.

The MES systems are responsible for carrying out the product manufacture, and all operations associated with the creation of those products. Recipes can be stored at the MES layer that detail the “How to build” instructions for the Control layer. These recipes are used for both labor and physical devices. As the MES systems work in short time spans, but normally not in the speeds associated with controls, the time factor is 10x.

Once the instructions, programs, documents, software, and other manufacturing requirements for support systems are transmitted, the Controls layer is then responsible for carrying out the process. Controls work in realtime; their time factor of 1x means that there are always operations occurring to refine, or correct, the process to maintain desired tolerances (or outputs). The dotted line boxes (Physical Devices and People) carry out the finite instructions for the process output.

**Components and Definition of Terms**

**Components of the Control layer**

The components of the Controls layer include, but are not limited to, controllers (programmable controllers, computers, robots, and DCS's (Distributed Control Systems), sensing devices, CNC (Computerized Numeric Controllers), user/operator interfaces, display devices, specialty software (including man/machine interface,
quality systems, control programming software, and automatic identification configurators), and intelligent input devices.

**Definition of Terms**

**User Interface Data** — Data necessary to communicate machine or process status to operators.

**Human/Machine Interface** — Software systems that graphically depict the status of machines, controls, and equipment that resides on the factory floor. H M I can also be hardware, such as an operator message display, that communicates the condition of the equipment or process/operation, or it can provide work instructions. HMI’s include: pushbutton stations; software; display stations; and message displays.

**Recipes** — Control or Process instructions that include: work instructions (both “what to build” and “how to build”) equipment instructions (what and how to use) operator instructions (who to use, when/how to use, safety, data collection, scheduling) machine instructions (which to use, how) scheduling instructions (when to build)

**Participants**

The following MESA International members participated in the development of this white paper:

**Individual**  
Maryanne Steidinger, Allen-Bradley Company  
Mark Muroski, ABB  
Scarlett Navarro-Robertroy, EDS  
Kirk Merley, EDS  
Tom Krzyzanowski, EDS  
John Lischefska, FACT  
Bob Olson, Hewlett-Packard Company  
Curtis Chance, Honeywell  
Tom Schaefer, Intermec  
Jeff Blossey, Intermec  
Mike Allen, Intermec  
John Leibert, MDS  
Jay Goldlist, Promis  
Bill Hakanson, MESA International

**Non-Member Participants**

Doug Furbush, Dun & Bradstreet Software  
Brandon Ekberg, Rockwell Software