MES Explained: A High Level Vision

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Executive Summary

Manufacturing Execution Systems (MES) deliver information that enables the optimization of production activities from order launch to finished goods. Using current and accurate data, MES guides, initiates, responds to, and reports on plant activities as they occur. The resulting rapid response to changing conditions, coupled with a focus on reducing non value-added activities, drives effective plant operations and processes. MES improves the return on operational assets as well as on-time delivery, inventory turns, gross margin, and cash flow performance. MES provides mission-critical information about production activities across the enterprise and supply chain via bi-directional communications.

This MESA International definition of Manufacturing Execution Systems (MES) bears deeper understanding. Why? Because of the benefits available through implementing this type of system. MES software has shorted manufacturing cycle times by an average of 45%, and has made major gains in decreasing in-progress inventory, defects, and reducing non-value adding paperwork. These substantial benefits are coming to companies that have already automated production lines, implemented enterprise-level software, and streamlined manufacturing processes as well as others.

The forces driving manufacturers to implement MES map directly to corporate business objectives and maintaining or gaining competitive advantage. This White Paper provides background and graphical models depicting the context, role, functions, software options, benefits, and technology trends for MES.

MES can be the core mission-critical system for plant managers and their staff. Financial, Materials planning, and Logistics personnel have long used computer applications to improve the accuracy and timeliness of their work; MES provides the same benefits to Operations. MES focuses on plant activities, and provides the minute-to-minute information needed to respond to events as they occur. Adding the power of computing to the core value-adding production process can pay for itself very rapidly.

MES is also an integrating set of functions—providing links between Planning and Control systems, design concept and product execution, sales force and delivery mechanisms, and customers and supply capabilities. MES combines both global and local rules into a plant-wide view of not only what is happening, but what *should* be happening to meet objectives. No other system contains equivalent functionality, or can deliver the same benefits. MES is essential not only to complete a manufacturing information system, but also to bring a manufacturer global competitiveness.

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Key To Reading

This document is designed to address the general needs of the manufacturing community. It is intended to be understandable and useful to everyone within a production organization. However, particular segments may be of keenest interest to certain audiences.

- **Corporate Executives** should read the Executive Summary, and will also find Section IV on Benefits of particular interest, since it ties MES into corporate performance measures. Section VI presents a vision of the drivers and future for manufacturers, and how MES plays into competitive success.
- **Financial management** will be most interested in Section IV on Benefits, which outlines what to expect from MES implementations, and assists with project cost justification. Section I also provides a view of how MES adds to and leverages other information system investments.
- **Information Systems** professionals will find of particular interest Section I that puts MES into context in the overall Manufacturing Software Architecture. In addition, Section V on Technology is directly aimed at the IS community.
- **Operations and Manufacturing** executives will find benefit from reading the entire document, since MES is the core information system that guides, initiates, responds to, and reports on plant activities as they occur. This White Paper provides an understanding of the context, functions, buying and configuring options, technologies, and justifications of systems that support the manufacturing functions.
- Those involved with **Materials Management, Purchasing, Accounting, Logistics, Supply Chain, Engineering,** and **Documentation** may be most interested in Sections I and II, which describe how MES relates to the systems they use, and what functions it offers that could complement or improve their systems.

I. MES in Context

For more than 25 years, manufacturing companies have been investing in computer systems to help run their operations. Early systems were custom built, with specific software developed for a particular manufacturer's operating style. However, in the past 10 years, commercial software products have garnered increasing market share. Some applications have gained major commercial market status, and are implemented widely. MRPII/ERP systems, CAD/CAM systems, and industrial Controls are prime examples of well-recognized manufacturing information systems.

Manufacturing Execution Systems (MES) is a term that represents a collection of functions that is different from any of these other areas, provides unique benefits when added to these other systems, and focuses on executing production activities – the core value-adding operations of a manufacturing company.

MES Defined

The MESA International definition is:

> "Manufacturing Execution Systems (MES) deliver information that enables the optimization of production activities from order launch to finished goods. Using current and accurate data, MES guides, initiates, responds to, and reports on plant activities as they occur. The resulting rapid response to changing conditions, coupled with a focus on reducing non value-added activities, drives effective plant operations and processes. MES improves the return on operational assets as well as on-time delivery, inventory turns, gross margin, and cash flow performance. MES provides mission-critical information about production activities across the enterprise and supply chain via bi-directional communications."

Fortunately, MES is available and already field-proven. MES can provide facility-wide views of critical production process and product data in a format that is usable by supervisors, operators, management, and others in the enterprise and supply chain. It provides "actuals" data from the facilities to feed financial system cost and performance roll-ups. It is a plant-wide system to guide activities on production lines so they meet global goals, not just local targets. The MES provides a current view of what is possible in production, providing a key piece information for quoting on real capabilities in supply chain management and sales activities, as well.

In many segments of industry, plant-wide functions are still handled by paper and manual systems (see Figure 1, Plant Information Model). Experienced personnel often carry the keys to production effectiveness in these factories. Manual systems and the judgment of experienced operations people will always play a role in most operations. However, just as accounting, materials management, engineering, and sales people have

benefitted from using more sophisticated computer software, so can plant managers, supervisors, and operators.

More and more manufacturers are feeling the pressures that MES can address. Many production plants are struggling to cope with a proliferation of product variations, which can render even the best human and paper systems ineffective and inefficient. Further, manual systems cannot keep pace with the increased speed of change in products, processes, technologies, and customer demands. Since operations change so rapidly, the timeliness of MES information is a key benefit, allowing response in seconds or minutes.

Delivery, quality, price and speed to market—these are the driving factors for manufacturers' excellence. Coupled with the pressures to meet external regulations, such as quality and customer certifications—a manufacturer must find ways to quickly and cost-effectively improve their yields within their manufacturing processes.

Supply chain pressures demand that many manufacturers have an accurate view of where products and materials are at all times, to effectively supply customers with product "Just In Time." The plant's status and capability to handle changes in production orders are further key pieces of information for supply in today's markets. As a result, many manufacturing companies are now making the transition from paper and manual systems to computerized MES (see Figure 1, Plant Information Model, bottom right).

MES In the Information Systems Architecture

MES is one of several major information system types aimed at manufacturing companies. Each of these system categories include various functions and product types. Major manufacturing software systems categories today are:

- **Enterprise Resources Planning (ERP)** – consists of those systems that provide financials, order management, production and materials planning, and related functions.
- **Supply Chain Management (SCM)** – includes functions such as forecasting, distribution and logistics, transportation management, electronic commerce, and advanced planning systems.
- **Sales and Service Management (SSM)** – comprises software for sales force automation, product configurators, service quoting, product returns, and so forth.
- **Product and Process Engineering (P&PE)** – includes computer aided design and manufacturing (CAD/CAM), process modeling, and product data management (PDM).
- **Controls** – are usually hybrid hardware/software systems such as distributed control systems (DCS), programmable logic controllers (PLC), distributed numerical control (DNC), supervisory control and data acquisition (SCADA) systems, and other computerized process control designed to control the way in which product is being manufactured.
- **Manufacturing Execution Systems (MES)** – consist of plant-wide information systems providing information on which to effectively execute operations to meet business goals. MES functions are described in more depth in Section II and the Appendix, and product types appear in Section III.

Most companies need some functionality from each of these six categories to succeed in their markets. The scope and detailed functionality needed from each application category may vary widely based on process mode (continuous, batch, discrete, assembly, or mixed mode) and business offering style (make-to-stock, repetitive, make-to-order, assemble-to-order, engineer-to-order). MES functionality and products are often—but not always—highly differentiated by process and offering style.

MES touches all of the other categories of information systems (see Figure 2, MES Context Model). This makes it both more important to the overall information infrastructure and also more challenging in some ways. Integration between MES and the other five major types of systems is a key to gaining full benefits not only of MES but also of these other information systems.

As the context model illustrates, MES provides a link between the various major types of systems. Some of these systems interface directly as well, but the MES interface generally links them to actual production status and capabilities. The context for MES is one of information flow from, to, and through the system. (For more detail refer to MESA White Paper No. 2 "*MES Functionalities and MRP to MES Data Flow Possibilities*" and No. 3 "*The Controls Layer: Controls Definition and MES to Controls Data Flow Possibilities*".)

From MES to Other Systems

As the core production execution system, MES feeds information to all of the other major types of systems:

- ERP relies on MES for "actuals" such as: costs, cycle times, throughput, and other production performance data.
- Supply Chain Management pulls data about actual order status, production capacities and capabilities, and shift-to-shift constraints from the MES;
- Sales and Service Management applications must also link in to MES, since their success in quoting and delivering depends on what is happening in the facilities at a given moment;
- Product and Process Engineering is fine-tuned based on the product yield and quality measured by the MES;
- Controls can get recipes and instructions downloaded that reflect the facility-wide optimum way to run at a given moment.

From Other Systems to MES

MES also takes in data from these other systems, ensuring that their information is acted on intelligently in the plant. For example, ERP's plans feed the MES work dispatch, and Supply Chain's master plans and schedules drive the timing of activities in the plant. Sales and Service configurations and quotes provide the baseline of order information for production, while product and process engineering drive work instructions, recipes, and operational parameters. Data from Controls is used to measure actual performance and operating conditions as they change in automated processes.

Overlaps But Unique Value

MES overlaps with these other systems, too. For example, either ERP or MES can dispatch work to the floor; both supply chain and MES include finite scheduling; process plans and documents can come from either product and process engineering or from the MES; both Controls and MES may include data collection functions. However, no other system contains equivalent functionality to MES.

While some similar-sounding functionality exists in ERP systems and control systems, the MES approach usually results in more focus on plant-wide production performance, and has deeper functionality for operations optimization. The MES functions are designed for direct access primarily by Operations personnel, from the plant manager to materials, maintenance, quality, and scheduling managers, to operators and technicians. These are the people that focus on manufacturing productivity.

Each of the other systems has its own core user group, as well. For example, an ERP system's shop floor control system is designed primarily to gather plant data that feeds the accounting and materials control system. MES's data acquisition can provide that same data, but also allows analysis against plant-level performance measures. Data acquisition and collection functions in Control Systems generally aim at improving the individual process or line under control, while in MES, this function aims more to analyze how effectively a given process is contributing to overall plant performance. *MES can leverage the investments in all of the other manufacturing information systems, as well as enabling improvements in plant operations.*

The role of MES, then, is to both oversee and record results of activities in a production facility. It gives a plant-wide view of the status and operation of processes, materials, human resources, machines, and tooling. In essence, the production knowledge – both of what is actually happening, and of what should happen – is captured in the MES. It is here that the overall effectiveness of a plant is both guided and measured.

MES gathers performance data to help run the plant and individual operations – as well as feed corporate data streams on costs, materials, and progress to plan. The unique plant-wide functionality of MES can leverage plant, capital, material, and human resource investments.

II. Functionality to Run Plants Effectively

Much like the other categories of systems, MES is not a single function. Think of all of the varied activities in the plant, and the grouping of measurements that indicate the success of a given plant. MES has functions that support, guide, and track each of the primary production activities (see Figure 3, MES Functional Model). MESA International has identified eleven principal functions of MES:

- **Operations/Detail Scheduling** - sequencing and timing activities for optimized plant performance based on finite capacities of the resources;
- **Resource Allocation and Status** - guiding what people, machines, tools, and materials should do, and

tracking what they are currently doing or have just done;
- **Dispatching Production Units** - giving the command to send materials or orders to certain parts of the plant to begin a process or step;
- **Document Control** - managing and distributing information on products, processes, designs, or orders, as well as gathering certification statements of work and conditions;
- **Product Tracking and Genealogy** - monitoring the progress of units, batches, or lots of output to create a full history of the product;
- **Performance Analysis** - comparing measured results in the plant to goals and metrics set by the corporation, customers, or regulatory bodies;
- **Labor Management** - tracking and directing the use of operations personnel during a shift based on qualifications, work patterns, and business needs;
- **Maintenance Management** - planning and executing appropriate activities to keep equipment and other capital assets in the plant performing to goal;
- **Process Management** - directing the flow of work in the plant based on planned and actual production activities;
- **Quality Management** - recording, tracking, and analyzing product and process characteristics against engineering ideals;
- **Data Collection/Acquisition** - monitoring, gathering, and organizing data about the processes, materials, and operations from people, machines, or Controls.

These eleven MES functions provide the core information base to run almost any type of plant (see Figure 3, MES Function Model). Plant managers, quality, maintenance, documentation, and scheduling managers all have tools in the MES arena. Most of what is tracked, managed, and analyzed to keep production at peak performance and profitability is available in MES functionality via computer. (See Appendix A for more detailed descriptions of the eleven MES functions.)

Many of these functions logically contribute to each other. For example, data collection and acquisition can automatically feed product genealogy, maintenance and labor tracking. Quality management feeds performance analysis as well as possibly sending trend data to maintenance management. Detailed scheduling often drives dispatching and resource allocation.

MES functions are critical to most manufacturers today because of business pressures that demand new and more stringent processes to succeed with both customers and shareholders. For example, correct allocation of resources can mean the difference not only between healthy and minimal profits, but also timeliness of production needed to fulfill customer expectations. Plant performance analysis is a key factor not only in deciding what and how much to produce in which plant, but also in capital planning for the future.

One of the most powerful aspects of MES is that it combines both global business rules and local operations best-practices into a plant-wide view of not only what is happening, but what should be happening to meet objectives. Users can configure this set of functionality to meet their corporate and plant objectives.

To define MES in the context of any given company, the manufacturer must identify core business drivers affected by how production is executed in the plant. While the core set of MES functions is relatively constant, the configuration and priorities may vary widely. For example, in some industries higher quality commands premium prices; in others, there is an accepted baseline of quality that is expected, and customers will not pay extra for a higher level. In another example, product genealogy is key to electronics and complex equipment companies' ability to satisfy customer demands for product information, reduce legal liability, keep improving product design, and provide ongoing maintenance and service. Repetitive and mass-market producers, on the other hand, usually do not need such detailed tracking, but may be heavily affected by scheduling sequence.

It's also interesting to note that achieving the same basic objectives may involve using different functionality. For example, many companies must keep yield and throughput high. Critical MES functions to achieve that goal could be any one of the following:

- process management – in plants with complex flow and high variability,
- maintenance – in highly automated, sensitive processes,
- labor management – for largely manual operations, or plants where employees have highly specialized skill sets,
- document control – in complex assembly or re-manufacturing operations,

- product genealogy and tracking – in highly regulated industries where paperwork problems are more likely to prevent product acceptance than production error,
- scheduling – where multiple products vying for a single resource can cause changeovers, wash downs or bottlenecks.

In addition to choosing systems with specific functions to meet business needs, many MES products provide mechanisms for configuration or tailoring to meet a particular plant's needs. At the core of many MES products is some type of model of the operation. Here, the user can model particular characteristics of the plant and the rules that govern the production. A small sampling of the rules that various MES functions may allow system users to configure are:

for many industries. And the type of document management needed can vary from CAD drawing displays with detailed work instructions for complex assembly and repair operations to simple forms-fill-out for customer certification documents.

Once the providers of MES software that match the basic production and business processes of the plant are identified, the issue of modeling the operations and configuring functions to match them becomes important. During the MES selection process, including Operations experts from the plant is advisable, since they know the details of how the processes run. Operations personnel need to advise both on the problems and the best solutions, to ensure the MES can support known best practices, or provide an equal level of performance.

Software Offerings

Because of the variation in product functionality and scope, there are literally hundreds of products that provide MES functionality. In fact, MES may come under any number of names (see Figure 5, MES Software Types). Some of them reflect one or a few of the eleven functions very directly; others provide some of those functions tightly integrated and sometimes with other functions included. So while most providers of maintenance management software don't think of themselves as MES vendors, they do provide a key set of functions that can benefit from integration with the other ten functions. Similarly, many quality management, advanced scheduling, and document management companies wrap the core MES functions in with non-plant-focused capabilities.

Given this variation in product offerings, buying MES requires preparation and diligence—and often the assistance of consultants or systems integrators. Plants must first identify the vendors who have experience not only in their industry, but also have written the code to fit the process mode and offering style profile of the facility. Buyers may also seek out a range of vendors offering the particular functions that are most important to competitiveness in that location. Once the software is carefully selected and the implementation is undertaken well, the benefits of operating a plant using MES can be enormous.

IV. Benefits of MES

MES has provided its users some of the most impressive benefits of any manufacturing software. MESA International's White Paper No. 1, "*The Benefits of MES: A Report from the Field*" outlines many of these issues based on actual MES user experiences. This research shows that the benefits users experience are significant. To quote a few statistics, MES:

- reduced manufacturing cycle time by an average of 45%;
- reduced data entry time, usually by 75% or more;
- reduced Work in Progress (WIP) an average of 24%;
- reduced paperwork between shifts an average of 61%;
- reduced lead time by an average of 27%
- reduced paperwork and blueprint losses an average of 56%
- reduced product defects an average of 18%.

The benefits listed are those that current MESA International research has validated. Note also that these users report gaining significantly more benefits over time. So this time sample represents some companies early in implementation and others much further along. Additional areas of benefit MESA can report on anecdotally (based on individual customer reports) include reduced overtime, faster production throughput, increased flexibility and agility, and cost avoidance in areas including compliance, WIP storage, and reduced scrap, rework, returns, and off-grade product.

MES provides dramatic benefits for a wide range of manufacturers, even with extensive software of other types installed. This is partly because MES functions focus on the core value-adding processes of a production company – the execution of the manufacturing process. So while most systems have focused on planning out how things should operate, MES focuses on improving how things actually are operating. MES applications improve the effectiveness of operations within a plant, and help plant personnel make sound decisions. The survey also indicates significant benefits from employee empowerment. By gaining immediate access to data, these companies have improved productivity, gained higher quality work, and been able to reduce supervision overhead.

On the operational front, MES provides significant gains toward the goals of plant managers, operations and production executives, and plant floor technicians and operators (see Figure 6, MES Operational Benefits). Notice that benefits go on a steeper curve with invest-

ments. These investments can be in additional MES functionality or products, enhancements of current functionality, investments in integration to other systems that pass data to and from the plant floor, or investments in training and innovating on systems.

These operational benefits contribute directly to corporate objectives. For example, improving the productivity of personnel by reducing data entry, paperwork and the time and error associated those activities can reduce liability, ease the path to regulatory compliance, reduce operating costs, improve customer service, and increase the return on human – and often other – assets. Rapid process upgrades can have a direct effect on the return on automation investments, operating expenses, delivery reliability, and overall profitability of operations. The corporate benefits of MES can be quite significant as well (see Figure 7, MES Corporate Benefits Model).

Building a Case for MES

Since MES applications are often not directly used by corporate-level personnel, the benefits may not be evident to these "financial buyers." Further, the MES core users are often not adept at extrapolating why benefits to them are also benefits to the corporation. The specialized terminology of not only financial and corporate management, but also of production operations, can deter communications of real and potential benefits to those who must make investment decisions. Thus a cross-functional team effort is often best to identify areas of desired improvement and build a cost-justification case.

A few common ways that different industries build the case for MES may help to illustrate the benefits case a given plant will build. It's common in many manufacturing industries for customer service to be a major corporate goal. MES contributes by shortening production cycle times, providing accurate information on the status of orders in production, and reducing errors in production that could cause delivery delays. Some industry-specific examples show greater differences:

- In electronics, MES is often justified on its ability to easily create an accurate product history and keep up with frequent changes in products and technology designs.
- Pharmaceutical companies can usually justify MES on the basis of accurate and easy-to-manage batch records for regulatory compliance and Good Manufacturing Practice (GMP).
- Aerospace & defense companies need on-line work instructions and product histories to meet regulations and customer certifications, keep errors in processing to almost zero, and track progress on very large projects.
- Textiles, food, and many batch process companies use MES functions to improve equipment utilization, assist in batch record-keeping, recipe management, and speed the process.
- Semiconductor companies simply cannot achieve the accuracy, cleanliness, and yield they need without MES; this industry would not consider building a new fab without an integrated MES.

Actual level of benefits gained—and benefits a given plant should expect—vary widely. This has to do with several factors, among them:

1. Whether the particular factor has been an issue for the plant already – in which case, changes in procedures, automation, and total quality techniques may have already gained improvements.

2. Which functions of MES a plant implements, and when. Naturally, plants that implement maintenance management functions could expect larger gains in equipment uptime than those that do not.

3. How well the software addresses the application and overall environment.

4. Whether the implementation was done with full support from top management, mid-management, and system users.

5. How carefully the impact on the corporation is – and can be – measured. In many cases, MES is implemented simultaneously with other software, automation, or improvement programs. While these projects can have tremendous results, it is often difficult to attribute benefits to any one component of the program.

V. MES Technology Trends

Since MES is really a collection of different types of software products, technologies used and planned may vary quite a bit per functional category, and even per product. However, some general technology trends are evident, through the diversity.

First, MES is a reasonably low-overhead set of applications. In most instances, it requires neither the complex graphics capabilities of a CAD/CAM system, the large

databases of ERP, nor the complex algorithms of supply chain software. The major requirement for MES is often a high number of users distributed on a network in sometimes harsh plant conditions. Many MES functions have long run on PCs and workstations. The advent of client-server technology, robust PCs and fail-safe local-area networks have been a major benefit to MES.

MES is following similar technology trends to many other types of manufacturing software. Most of the systems are client-server, use relational databases, and run on UNIX, VMS, OS/400, Windows NT, or Windows 3.1 or 95. Most of the commercial products provide application programming interfaces (APIs) to connect to other applications such ERP, Controls, Supply Chain, Product and Process Engineering, and Sales and Service Management (see Figure 8, MES Current Technology Model).

What all of this means is that technology is not the driving issue behind MES adoption or effectiveness. As technology has progressed, MES has taken advantage of improvements and migrated from one generation to the next, without ever stretching the limits of commercial technology or manufacturers" ability to purchase and support it.

The government-sponsored Solutions for MES-Adaptable Replicable Technology (NIIIP/SMART) consortium, which MESA International participates in, has identified four major business characteristics driving MES implementation architectures.

1. Low Capital Expenditures – This factor drives toward users that change systems in the plant more slowly than the technology evolves, PC-based architectures, and a thin-client architecture, in which application logic resides mostly on the server.

2. High Degree of Change – Data capture and archiving becomes important to track the rapid change in a plant. How much data to store actively versus put in an archive becomes a trade-off between operational analysis capabilities and storage and processing burdens.

3. Short Cycle Time – The speed at which products move through a plant also dictates how rapidly transactions must be processed to measure operational performance.

4. Functionality Flexibility – Because plants vary so widely, MES products will specialize based on which attributes they can handle, and how configurable they are.

One complicating factor is that a single plant may implement software from more than one provider – or use legacy systems for some portion of the MES functionality. So the result in many plants is a patchwork of systems, each with its own logic, database, data model, and communications mechanisms (represented in Figure 8 by dotted lines). Further, since MES applications are often mission-critical, systems may not be replaced or updated nearly as often as the technology changes are commercially available.

MES is essentially an integrating set of functions – providing links between planning and control, design concept and product execution, sales force and delivery mechanisms, and customers and supply capabilities. So the APIs and data transport or communications mechanisms are, in some ways, a core piece of MES functionality, not just an incidental technical detail.

Object-oriented technologies, using messaging and agents, are emerging as manufacturing software directions. MES is moving to these modern technologies, because these new architectures promise easier integration, faster change, more ability for subject matter experts to configure systems, and effective infrastructure for triggering mission-critical events.

The NIIIP/SMART consortium is working toward a technology architecture that would provide a consistent distributed object and messaging model for the entire MES arena (see Figure 9, MES Future Technology Model). Notice that in the object-oriented world this new technology represents, objects carry their own functions and methods to operate on data. However, a range of functions for workflow, knowledge, and product data management, data mediation and resource negotiation are now separated out from the functional logic. Consistent object request brokers (ORBs) such as CORBA and COM/DCOM allow any vendor's objects written to those standards to communicate and interoperate.

NIIIP/SMART indicates that this architecture helps meet MES business characteristics. A distributed object framework allows data and functional logic to be carried close to where it is used. Further, by using small, fine-grain objects, the model is highly customizable without destroying the relationships of the model. These characteristics help keep capital expenses low, allow rapid

change and quick response, and result in flexibility for MES.

Beyond allowing the MES applications to meet their goals more easily, this new technology architecture will also allow MES to interoperate with the other five categories of manufacturing software relatively seamlessly. As more and more MES, ERP, Controls, Product and Process Engineering, Supply Chain Management, and Sales and Service Management software is written in objects, to conform with the same ORB, the vision of integrated manufacturing systems functionality will be possible for manufacturers to implement. Even though these systems will continue to be developed and sold by different companies for some time, the internal architecture will be more consistent than possible previously.

VI. Drivers for MES & Future Considerations

Leading manufacturers are making decisions to invest in MES now, if they have not already. MES addresses business drivers in many ways:

- To respond more rapidly in production to changes in the marketplace, MES provides an ability to execute differently than planned.
- To increase profits, MES enables plants to produce more cost-effectively and use plant resources wisely—not just by keeping utilization high, but by ensuring activities are optimized to business needs for profits and customer satisfaction.
- Operations personnel are empowered by MES; it helps ensure their expertise is leveraged in ways that are adequate in new situations.
- As new technologies increase the sensitivity of production processes, MES can provide structure to execute them properly.
- Short product lifecycles make the MES assistance with achieving full yield and plant productivity essential.
- Regulatory and customer compliance demands are increasingly difficult and costly to meet without MES automating accurate recording of data on products and processes, as well as providing instant access to safety, health, and regulatory information.
- Return on Investments (ROI) in assets from human resources to equipment, tools, materials, and even other information systems can improve when MES is connected, driving production in harmony with other activities.

In addition, companies are realizing that their information infrastructures have gaps. While the actual process is often highly automated, and financial, design, planning, and other office and field operations use sophisticated systems, *all of their plans and assumptions are only as good as the data feeding them about actual production and plant capabilities.* Even when the data is good in a company, it's rarely available in a timely fashion to the operations personnel who must decide what activities a plant undertakes.

Most manufacturing is at a stage where flexibility and speed demands are extreme, and getting more critical. There are cost, compliance, yield, and service issues to balance in running operations. MES is a key enabler for manufacturers to execute as they want to: rapidly, reliably, and in an agile manner.

Competitive pressures in nearly every manufacturing industry are indicating a need for better information systems, and better integration between the systems and people who use them. Few production companies fail now to recognize that knowledge is power. And MES provides the knowledge about the core value-adding processes of a manufacturer—the production processes.

Appendix A: MES Functions

1. Resource Allocation and Status
Manages resources including machines, tools labor skills, materials, other equipment, and other entities such as documents that must be available in order for work to start at the operation. It provides detailed history of resources and insures that equipment is properly set up for processing and provides status real time. The management of these resources includes reservation and dispatching to meet operation scheduling objectives.

2. Operations/Detail Scheduling
Provides sequencing based on priorities, attributes, characteristics, and/or recipes associated with specific production units at an operation such as shape of color sequencing or other characteristics which, when scheduled in sequence properly, minimize set-up. It is finite and it recognizes alternative and overlapping/parallel operations in order to calculate in detail exact time or equipment loading and adjust to shift patterns.

3. Dispatching Production Units
Manages flow of production units in the form of jobs, orders, batches, lots, and work orders. Dispatch information is presented in sequence in which the work needs to be done and changes in real time as events occur on the factory floor. It has the ability to alter prescribed schedule on the factory floor. Rework and salvage processes are available, as well as the ability to control the amount of work in process at any point with buffer management.

4. Document Control
Controls records/forms that must be maintained with the production unit, including work instructions, recipes, drawings, standard operation procedures, part programs, batch records, engineering change notices, shift-to-shift communication, as well as the ability to edit “as planned” and “as built” information. It sends instructions down to the operations, including providing data to operators or recipes to device controls. It would also include the control and integrity of environmental, health and safety regulations, and ISO information such as Corrective Action procedures. Storage of historical data.

5. Data Collection/Acquisition
This function provides an interface link to obtain the intra-operational production and parametric data which populate the forms and records which were attached to the production unit. The data may be collected from the factory floor either manually or automatically from equipment in an up-to-the-minute time frame.

6. Labor Management
Provides status of personnel in and up-to-the-minute time frame. Includes time and attendance reporting, certification tracking, as well as the ability to track indirect activities such as material preparation or tool room work as a basis for activity based costing. It may interact with resource allocation to determine optimal assignments.

7. Quality Management
Provides real time analysis of measurements collected from manufacturing to assure proper product quality control and to identify problems requiring attention. It may recommend action to correct the problem, including correlating the symptom, actions and results to determine the cause. May include SPC/SQC tracking and management of off-line inspection operations and analysis in laboratory information management system (LIMS) could also be included.

8. Process Management
Monitors production and either automatically corrects or provides decision support to operators for correcting and improving in-process activities. These activities may be intra-operational and focus specifically on machines or equipment being monitored and controlled as well as inter-operational, which is tracking the process from one operation to the next. It may include alarm management to make sure factory person(s) are aware of process changes which are outside acceptable tolerances. It provides interfaces between intelligent equipment and MES possible through Data Collection/Acquisition.

9. Maintenance Management
Tracks and directs the activities to maintain the equipment and tools to insure their availability for manufacturing and insure scheduling for periodic or preventive maintenance as well as the response (alarms) to immediate problems. It maintains a history of past events or problems to aide in diagnosing problems.

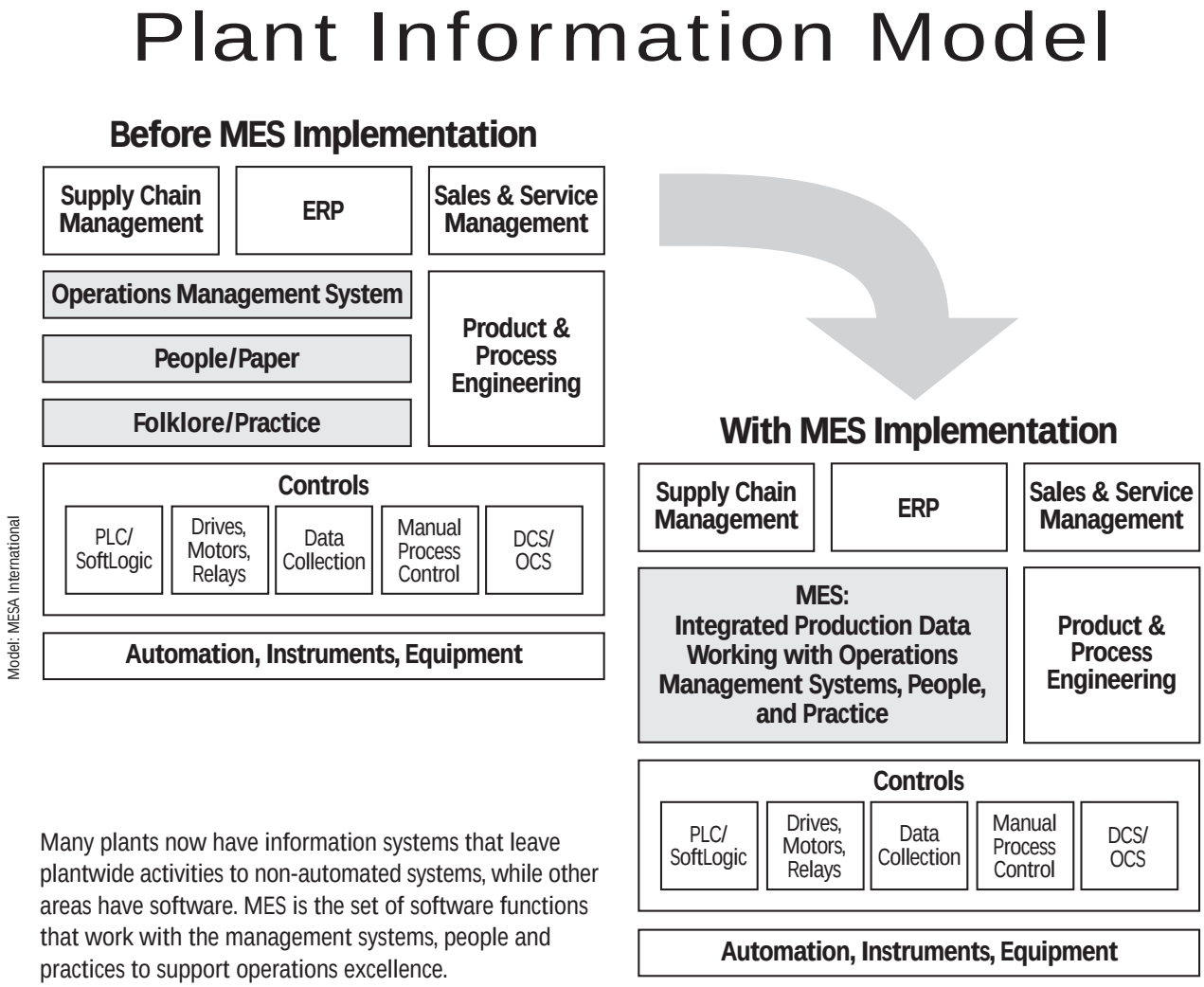
10. Product Tracking and Genealogy
Provides the visibility to where work is at all times and its disposition. Status information may include who is working on it; components materials by supplier, lot, serial number, current production conditions, and any alarms, rework, or other exceptions related to the product. The on-line tracking function creates a historical record, as well. This record allows traceability of components and usage of each end product.

11. Performance Analysis
Provides up-to-the-minute reporting of actual manufacturing operations results along with the comparison to past history and expected business result. Performance results include such measurements as resource utilization, resource availability, product unit cycle time, conformance to schedule and performance to standards. May include SPC/SQL. Draws on information gathered from different functions that measure operating parameters. These results may be prepared as a report or presented on-line as current evaluation of performance.

Appendix B: Models

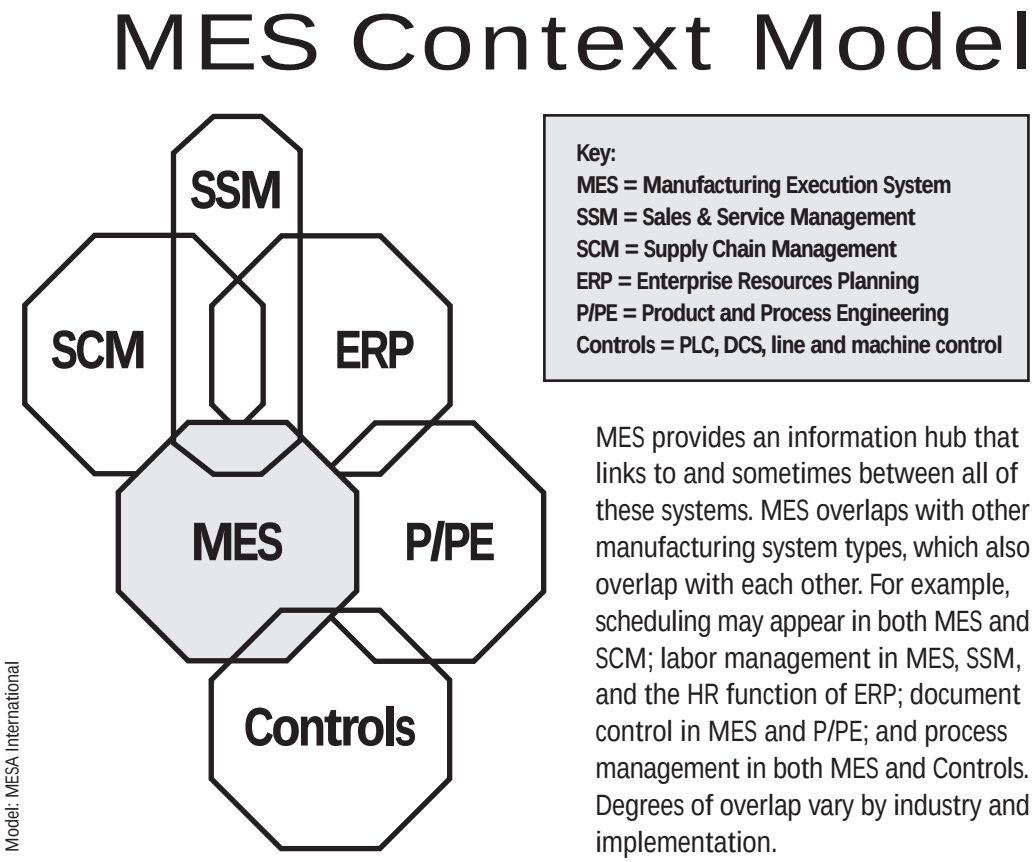
The following figures are intended to further the understanding of MES; we encourage you to reproduce and distribute them.

Figure 1, Plant Information Model



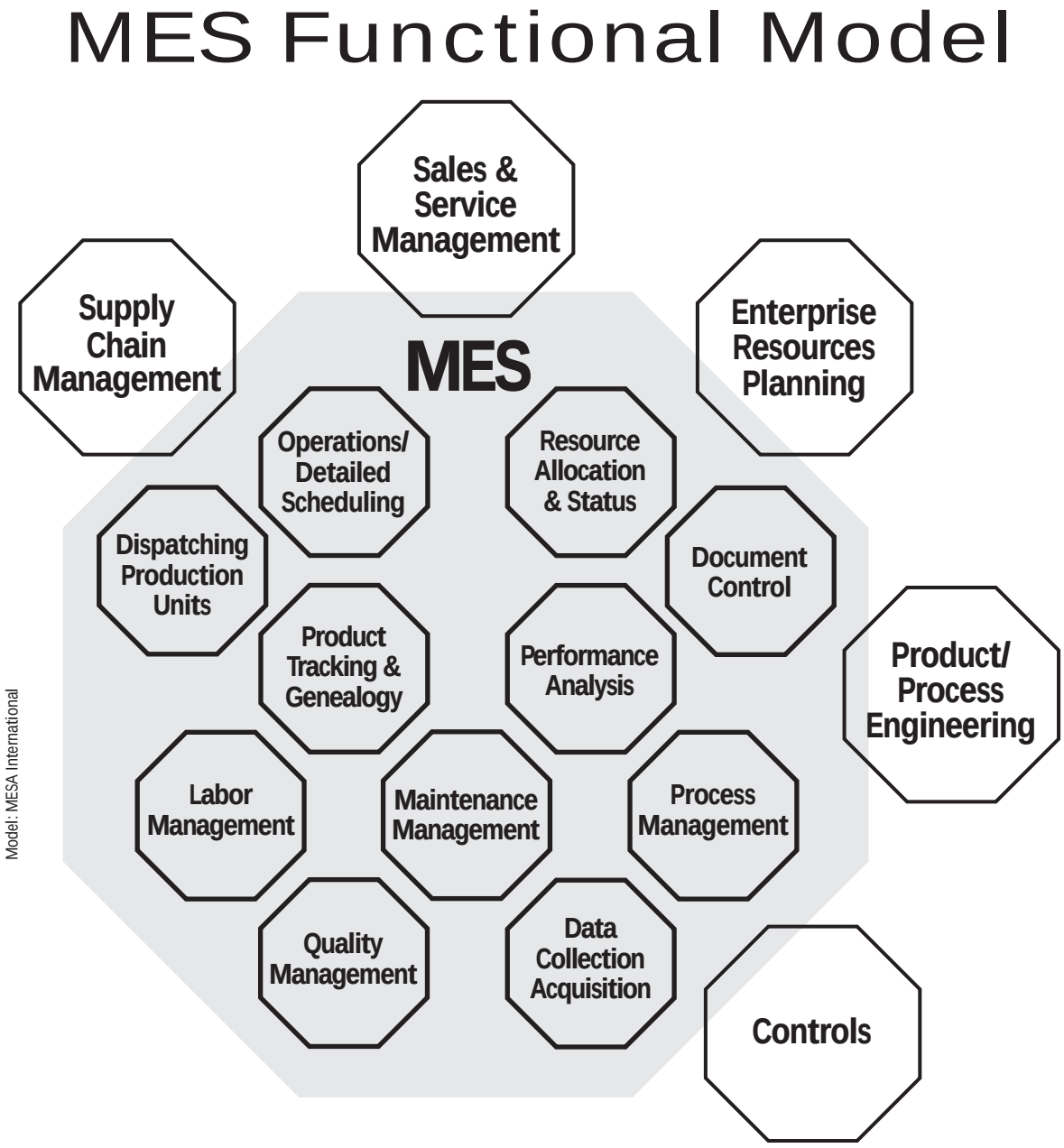
Many plants now have information systems that leave plantwide activities to non-automated systems, while other areas have software. MES is the set of software functions that work with the management systems, people and practices to support operations excellence.

Figure 2, MES Context Model



MES provides an information hub that links to and sometimes between all of these systems. MES overlaps with other manufacturing system types, which also overlap with each other. For example, scheduling may appear in both MES and SCM; labor management in MES, SSM, and the HR function of ERP; document control in MES and P/PE; and process management in both MES and Controls. Degrees of overlap vary by industry and implementation.

Figure 3, MES Functional Model



This model shows the eleven functions of MES and links to other systems. Functions may link in multiple different ways by product and need.

Figure 4, MES Producer/Consumer Model

Model: MESA International

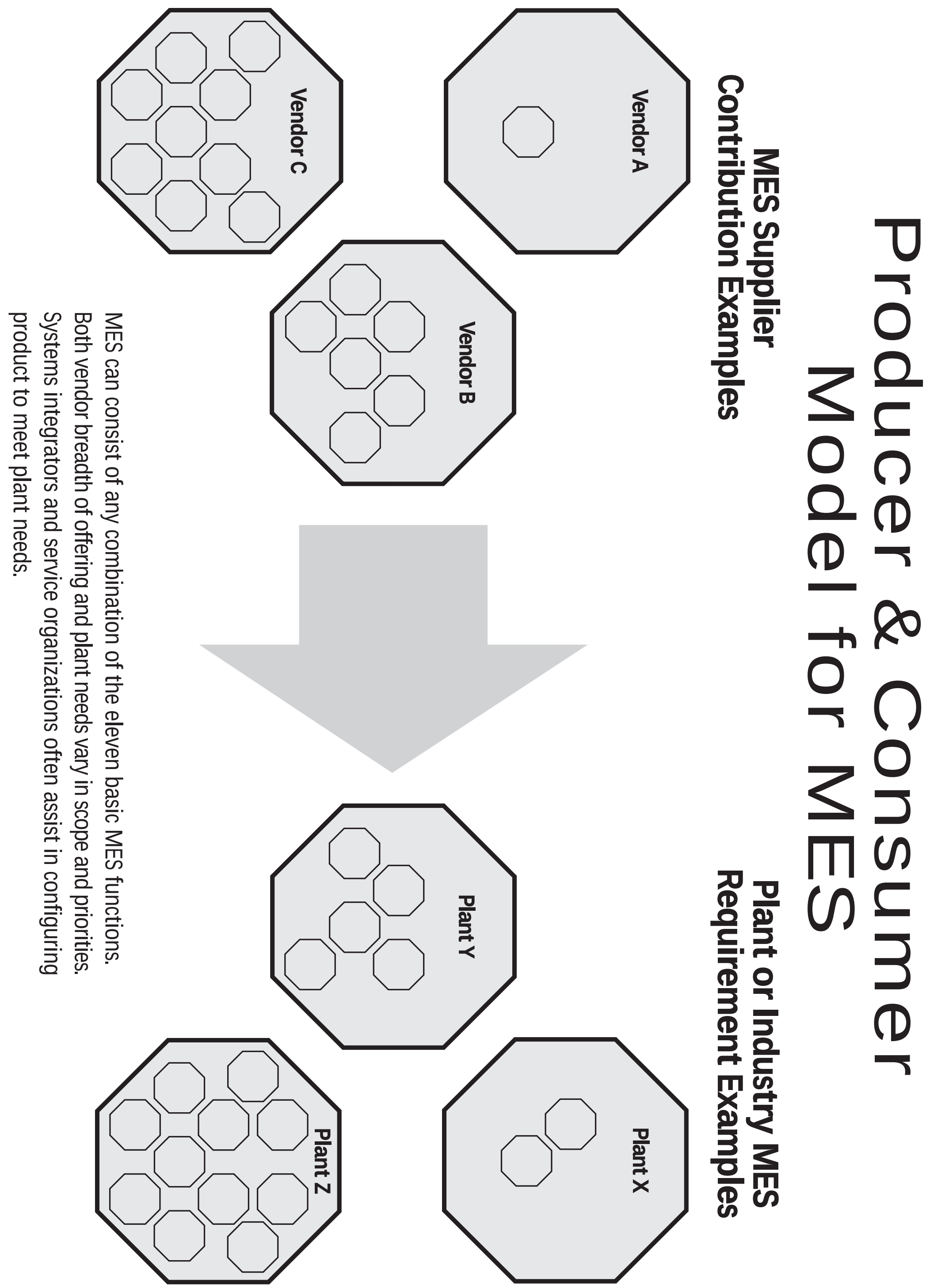


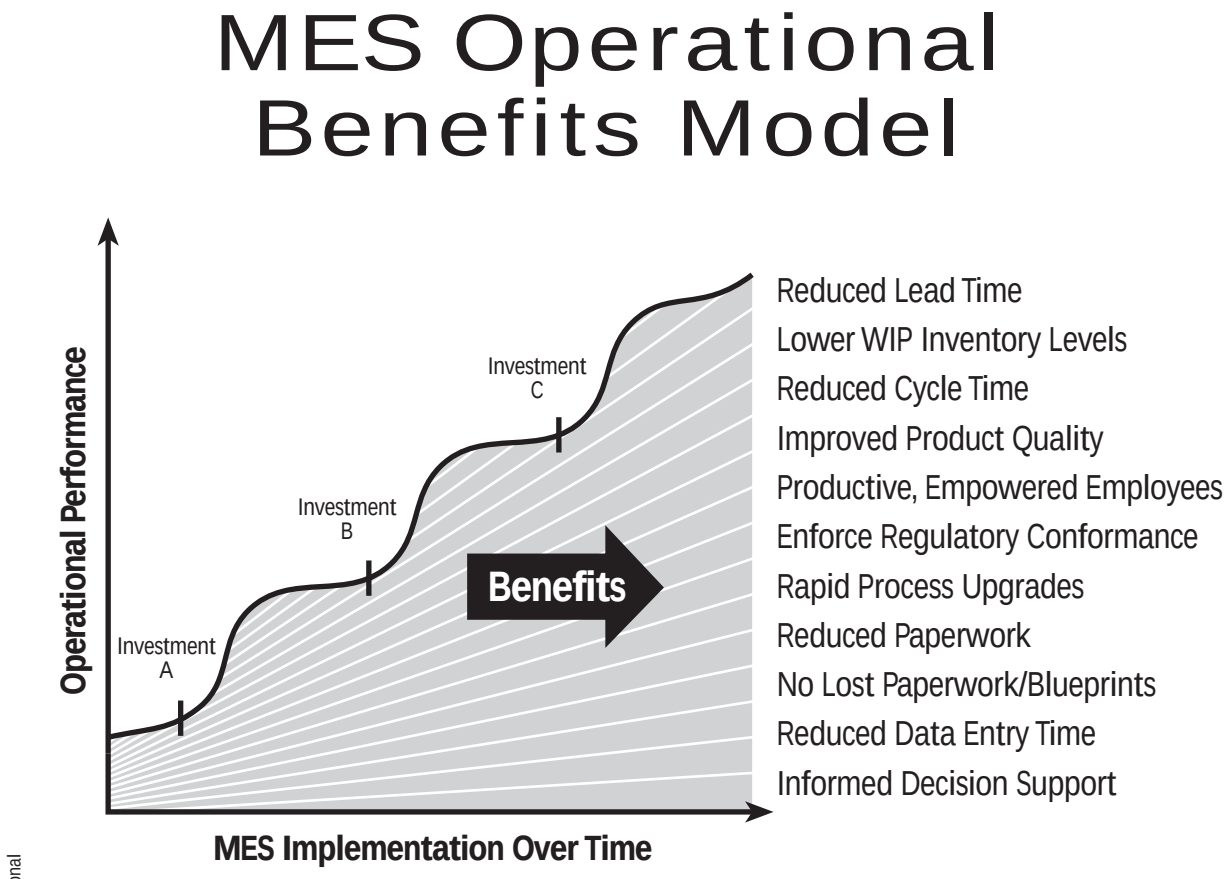
Figure 5, MES Software Types

Typical Product Categories With MES Functions

Batch Management
Computer Aided Process Planning
Data Collection, Auto ID, Barcode
Electronic Batch Management (EBR)
Electronic Document Management
Electronic Work Instructions
Finite Scheduling
Integrated MES
Laboratory Information Systems (LIMS)
Maintenance or Asset Management
Process Simulation
SPC, QC, Quality Management
Time & Attendance
WIP Tracking

Software products that provide MES functionality come under a variety of names that don't necessarily map directly to the eleven functions. These are representative MES product types.

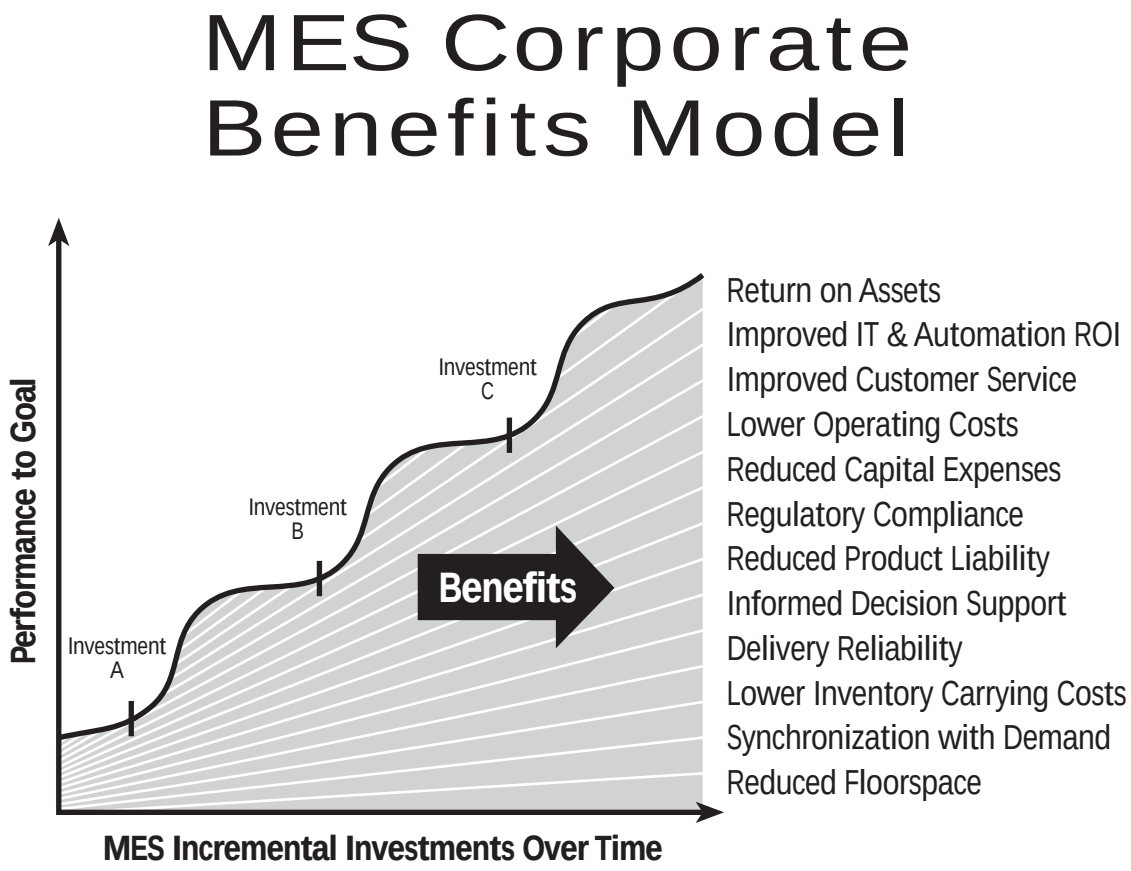
Figure 6, MES Operational Benefits



Model: MESA International

MES provides most industries a wide range of operational benefits, even for companies that have other systems in place. Several MES solutions or functions may contribute to the strength of a given benefit, and benefits may also be increased by appropriate process improvements. Benefits accrue in different sequences, based on the functionality chosen, project focus, integration to other systems, and the plant's driving needs.

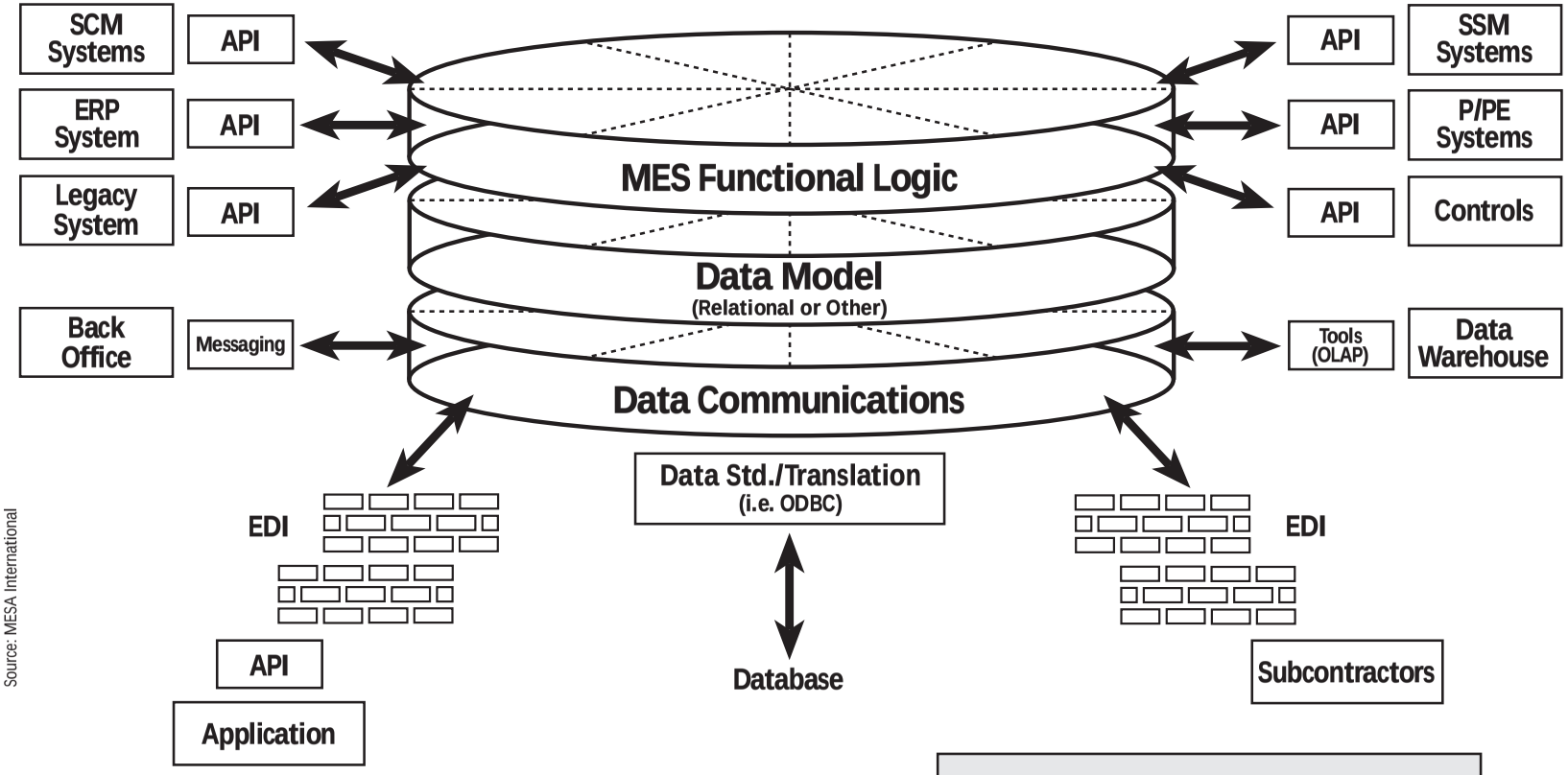
Figure 7, MES Corporate Benefits Model



Model: MESA International

MES contributes to most industries' corporate goals, even for companies that have other systems in place. Several MES solutions or functions may contribute to the strength of a given benefit, and benefits may also be increased by appropriate process improvements. Benefits accrue in different sequences, based on the functionality chosen, project focus, integration to other systems, and driving needs.

MES Current Technology Model



Source: MESA International

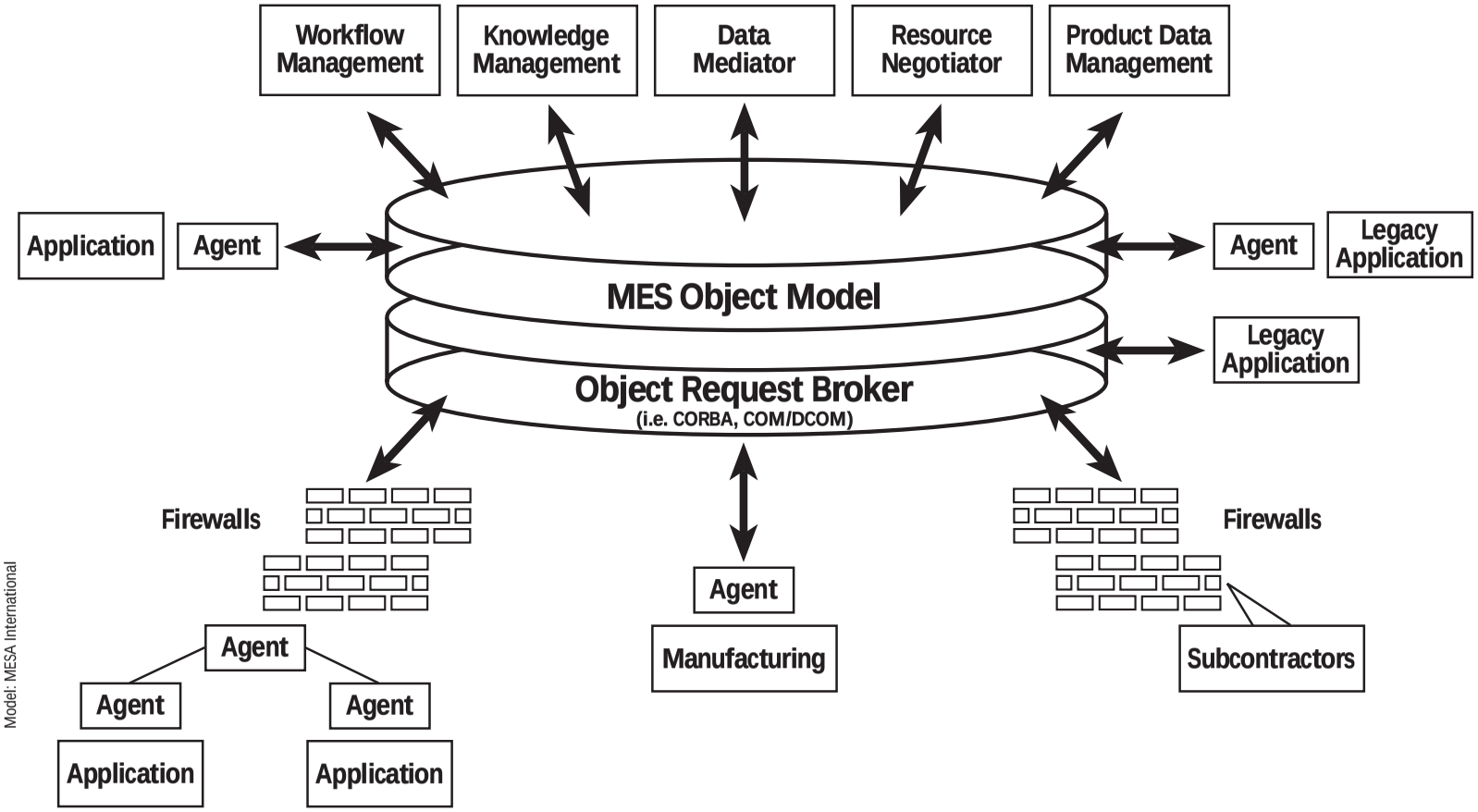
Figure 8, Current Technology Model

Current MES architecture incorporates a data model and communication mechanism per vendor's system — which could represent one or many MES functions, plus APIs for interfacing to external systems and EDI to link outside the corporation.

Based on: NIIIP-SMART Reference Architecture As-Is Model

Key:
API = Application Program Interface
OLAP = On-Line Analytical Processing
EDI = Electronic Data Interchange
--- = separation between potentially different systems

MES Future Technology Model



Model: MESA International

Figure 9, Future Technology Model

MES is incrementally evolving toward a consistent object model, along with the rest of the software industry. In this future information systems model, MES uses an object request broker to pass manufacturing events to workflows, agents, and external systems (SCM, ERP, Legacy, SSM, P/PE, Controls, Data Warehouse) through data mediation. Unique plant business policy is represented as sets of rules within knowledge management which can initiate manufacturing events.

Source: NIIIP-SMART Reference Architecture

Appendix C: Glossary of Terms

API - Application Programming Interface

Auto ID - Automatic Identification such as Bar coding, RF tags, etc.

CAD/CAM - Computer Aided Design and Computer Aided Manufacturing

DCS - Distributed Control System

DNC - Distributed Numerical Control

ERP - Enterprise Resources Planning

GAAP - Generally Accepted Accounting Principles

GMP - Good Manufacturing Practice

LIMS - Laboratory Information Management Systems

MES - Manufacturing Execution System

MRP - Material Requirements Planning

MRPII - Manufacturing Resources Planning

NIIIP/SMART - National Industrial Information Infrastructure Protocols Solutions for MES-Adaptable Replicable Technology

ORB - Object Request Broker

PC - Personal Computer

PLC - Programmable Logic Controller

ROI - Return on Investment

P/PE - Product and Process Engineering

QC - Quality Control

SCADA - Supervisory Control and Data Acquisition

SCM - Supply Chain Management

SPC - Statistical Process Control

SSM - Sales and Service Management

WIP - Work-in-Progress or Work-in-Process

Participants

This report is an outcome of a year's project initated and funded by MESA. Julie Fraser of Industry Directions was engaged to support the effort and prepared this document as part of her work. Significant contributions were made many MESA members including:

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